

CALFED

**TECHNICAL REPORT
AFFECTED ENVIRONMENT**

GEOLOGY & SOILS

DRAFT

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LIST OF ACRONYMS

CALFED	CALFED Bay-Delta Program
CDMG	California Division of Mines and Geology
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CVP	Central Valley Project
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
NRCS	Natural Resources Conservation Service
Reclamation	U.S. Bureau of Reclamation
SJVDP	San Joaquin Valley Drainage Program
STATSGO	State Soil Geographic Data Base
SWP	State Water Project
USGS	U.S. Geological Survey

GEOLOGY & SOILS

INTRODUCTION

This technical report describes characteristics of geomorphology and soils that could be affected by implementation of the CALFED Bay-Delta Program (CALFED).

Key resource categories and assessment variables described in this report include fluvial geomorphology, especially erosion and sedimentation; oxidation, wind erosion, and land subsidence; soil salinity and drainage problems; and seismicity.

Geologic characteristics are not likely to be affected directly by CALFED alternatives. Geomorphologic and soils characteristics are likely to be directly affected to various degrees because they are strongly influenced by underlying geology and surface physical processes. Geology and physical processes, therefore, are included in this affected environment description.

SOURCES OF INFORMATION

Soils information was obtained from the State Soil Geographic Data Base (STATSGO); from soil survey reports for Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (NRCS 1972, 1977a, 1977b, 1992, and 1993b); and through personal communications with Natural Resources Conservation Service (NRCS, formerly Soils Conservation Service) district conservationists.

Additional sources were used for specific information on subsidence (DWR 1986 and 1989, Rojstaczer et al. 1991, and Rojstaczer and Deverel 1993), seismicity (Finch 1992, Kearney 1980), and salinity (Meyer et al. 1979, Orlob 1987).

Geology information for this report was collected from the U.S. Geological Survey (USGS), California Division of Mines and Geology (CDMG), and the California Division of Oil and Gas. Other private publications on state geology also were reviewed.

The discussion of Delta sedimentation and scour is based on an investigation conducted by De Groot et al. (1984), in which numerous publications and data sources were consulted, including agency and private publications; agency gaging stations; and cross section surveys conducted by the U.S. Army Corps of Engineers (Corps), USGS, and the California Department of Water Resources (DWR).

ENVIRONMENTAL SETTING

Regulatory Context

Regulations relevant to the use and farming of soils include 1985 and later Farm Bills, state water quality control plans, and gravel mining ordinances. The provisions of the 1985 and later Farm Bills require erosion control plans for highly erodible lands in order for farmers to participate in agricultural commodity programs. In the study area, the provisions for highly erodible lands apply mainly to the organic soils in the Delta because of their susceptibility to wind erosion. Water erosion is not a significant problem on level and nearly level lands of the Delta, only on the channel substrates and banks.

Water quality regulations also indirectly affect soil conditions by controlling the salinity of irrigation water. If the salinity of Delta waters was not controlled by regulating saline discharges, ocean salinity intrusion, and freshwater releases from reservoirs, soils in the southern and western parts ultimately could become too saline for agricultural use. In recognition of potential problems caused by

instream gravel mining, Shasta and Tehama counties have enacted gravel mining ordinances that serve to protect critical fish spawning areas.

All Regions

Different geologic processes acting on various rock formations over millions of years have created many geologically different areas within the state. The areas have been grouped into eleven geologic provinces. From north to south, they are the Coast Ranges, Klamath Mountains, Cascade Range, Modoc Plateau, Central Valley, Sierra Nevada, Basin and Range, Mojave Desert, Transverse Range, Peninsular Range, and the Salton Trough. The study area for this investigation includes all of the provinces mentioned except the Basin and Range, and Salton Trough. Figure 1 shows all the geologic provinces in the state.

The Central Valley geologic province is a valley trough that extends over 400 miles from north to south, and consists of the Sacramento Valley and the San Joaquin Valley. The San Joaquin Valley is comprised of the San Joaquin River basin, drained by the San Joaquin River from the south, and the Tulare basin, a hydrologically closed basin that is drained only during extremely wet periods. The Sacramento Valley is drained by the Sacramento River from the north. The confluence of these two major river systems and lesser streams and systems forms the inland Delta, which is drained through Suisun Bay and the narrow Carquinez Strait, into San Pablo and San Francisco bays, and into the Pacific Ocean.

Underlying the study area and the Central Valley geologic province are 6 to 10 vertical miles of accumulated marine and continental sediments. The marine sediments were deposited from pre-Tertiary periods to the late Pliocene epoch in parts of the San Joaquin Valley. By the late Pliocene, the Coast Ranges had formed, the seas had receded, and continental sediments were deposited on top of the marine sediments.

The upper and lower watersheds of the study area contain four primary land types, each with characteristic soil conditions: valley land, valley basin land, terrace land, and upland (Figure 2). Valley land and valley basin land soils occupy most of the Central Valley floor. Valley land soils consist of deep alluvial and aeolian soils that make up some of the best agricultural land in the state. Valley basin lands consist of organic soils of the Sacramento-San Joaquin Delta, poorly drained soils, and saline and alkali soils in the valley trough and on the basin rims. These soils are mainly used for pasture, rice, and cotton. Areas above the Central Valley floor consist of terrace and upland soils. Overall, these soils are not as productive as the valley land and valley basin land soils.

Upland soils are found on the hilly to mountainous topographic areas surrounding the Central Valley and are formed in place through the decomposition and disintegration of the underlying parent material. Deep upland soils occur in the high rainfall zones at the higher elevations in the mountains surrounding the valley, and are important timberlands, characterized by acid reaction and depths to bedrock of three to six feet. Shallow upland soils occur in the medium-to-low rainfall zones at lower elevations. They range from calcic brown stony clay (for example, in Lassen soils) to noncalcic brown loam (for example, in Vallecitos soils). Without irrigation, these soils are primarily used for grazing and timberland; with irrigation, additional crops can be grown. Very shallow upland soils are found on steep slopes, often at high elevations. They consist of stony clay loam or stony loam and are not useful for agriculture or timber because of their very shallow depth, steep slopes, and stony texture. As such, they are also rated very low for grazing purposes.

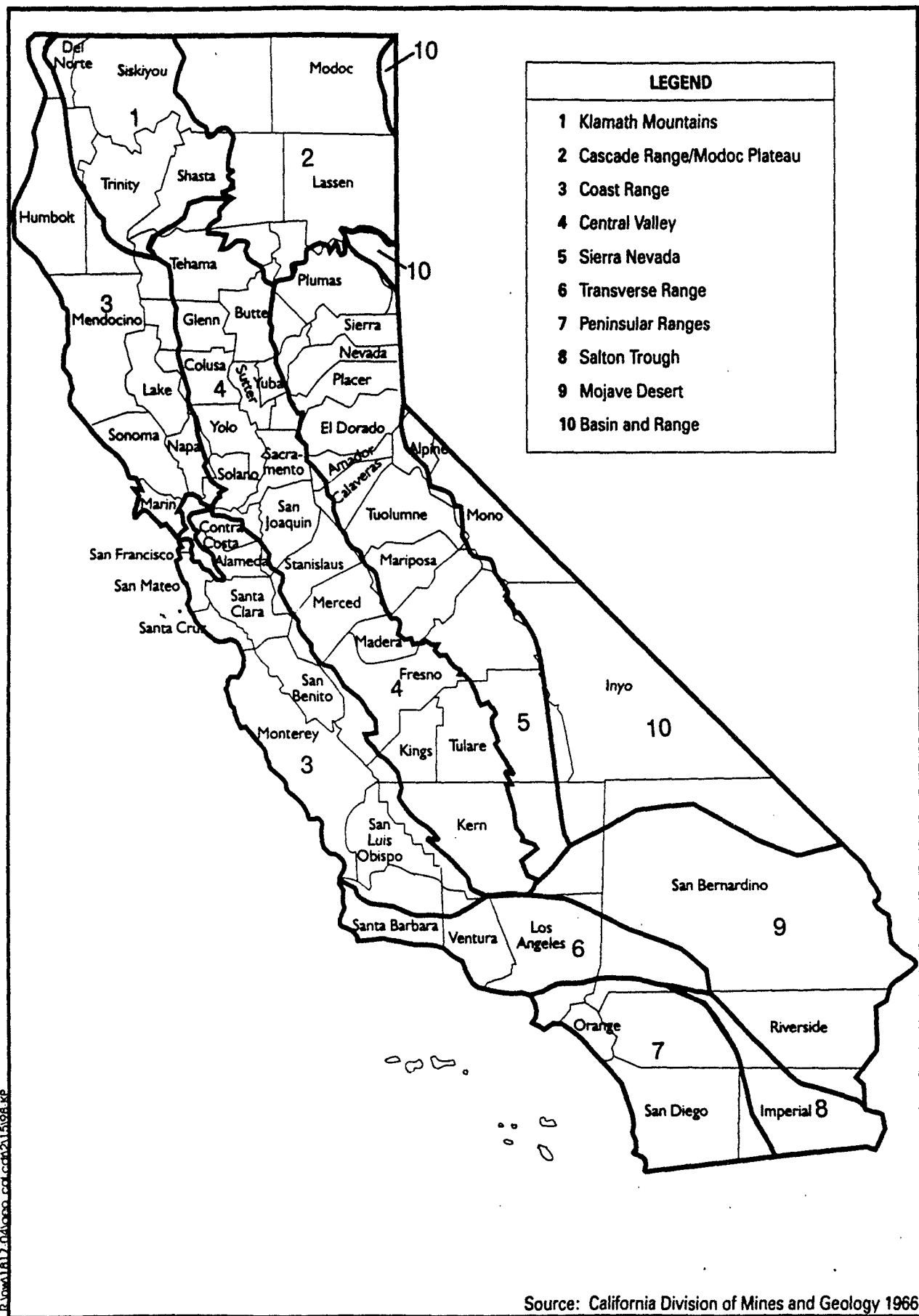


Figure 1. Geologic Provinces

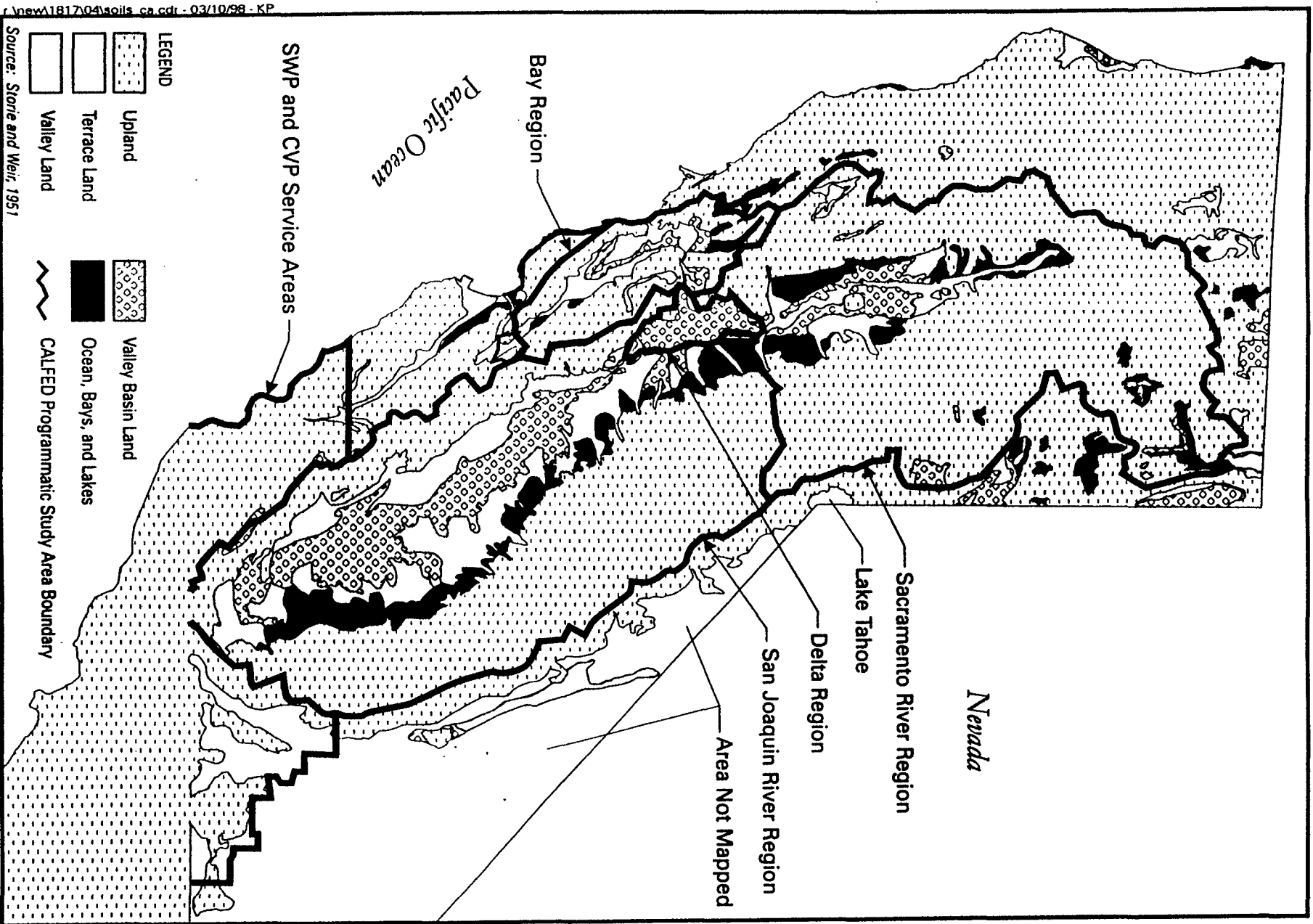


Figure 2. Soil Types in the Central Valley

The major factor affecting geologic and soil resources in the upper watersheds of the Bay Region are urbanization, whereas, these same resources in the upper watersheds of the Sacramento River and San Joaquin River regions are primarily influenced by excessive grazing and logging.

Delta Region

HISTORICAL PERSPECTIVE

The Delta, a triangular-shaped network of channels and islands, is the meeting point for the Sacramento, San Joaquin, and Mokelumne rivers. In the most recent natural development of the Delta, the river system formed a large number of islands.

The Delta islands have been reclaimed for agricultural use because of their fertile soils. Conversion of the Delta wetlands to farmlands began in 1850 when the federal government transferred ownership of "swamp and overflow" lands to the states. Substantial reclamation was accomplished between 1880 and 1920. By 1930, the Delta was essentially developed to its current configuration (De Groot et al. 1984).

Development of the islands resulted in subsidence of the island interiors and greater susceptibility of the topsoil to wind erosion. Subsidence, as it relates to Delta islands, refers generally to the falling level of the land surface that results from the processes of peat soil oxidation and wind erosion of the surface soil layers.

By 1920, it was recognized that the drained Delta lands were subsiding. In 1922, the University of California began a study to measure subsidence (Weir 1950). Elevation measurements made from 1922 to 1981 indicate that agricultural practices, regardless of crop type, tended to cause 1 to 3 inches of subsidence per year (USGS 1991).

When organic soils are dry, they are very light and highly susceptible to wind erosion, particularly when vegetative cover is sparse or absent. These conditions often can occur during spring, when fields are being prepared for planting and a crop cover is not yet in place.

Although California is the most seismically active area in the United States, the Delta region has been relatively inactive. The active faults in or near the Delta with movement within the historic record include the Concord, Greenville, Hayward, and San Andreas faults (Figure 3).

Historically, the Delta has not suffered catastrophic earthquake damage.

DELTA REGION - CURRENT RESOURCE CONDITIONS

SOILS DESCRIPTION

The soils of the Delta Region vary primarily as a result of difference in climate, parent material, biologic activity, topography and time. For the purposes of this discussion, the soils are divided into four general soil types:

- Delta organic soils and highly organic mineral soils,
- Sacramento River and San Joaquin River deltaic soils,
- Basin and basin rim soils, and
- Moderately well- to well-drained valley, terrace, and upland soils.

Additional information on these soils can be found in the Geology & Soils Supplement, at the end of this document.

The Delta Region contains primarily farmlands with the appropriate physical and chemical soil characteristics, growing season, and moisture supply necessary to qualify as prime farmlands.

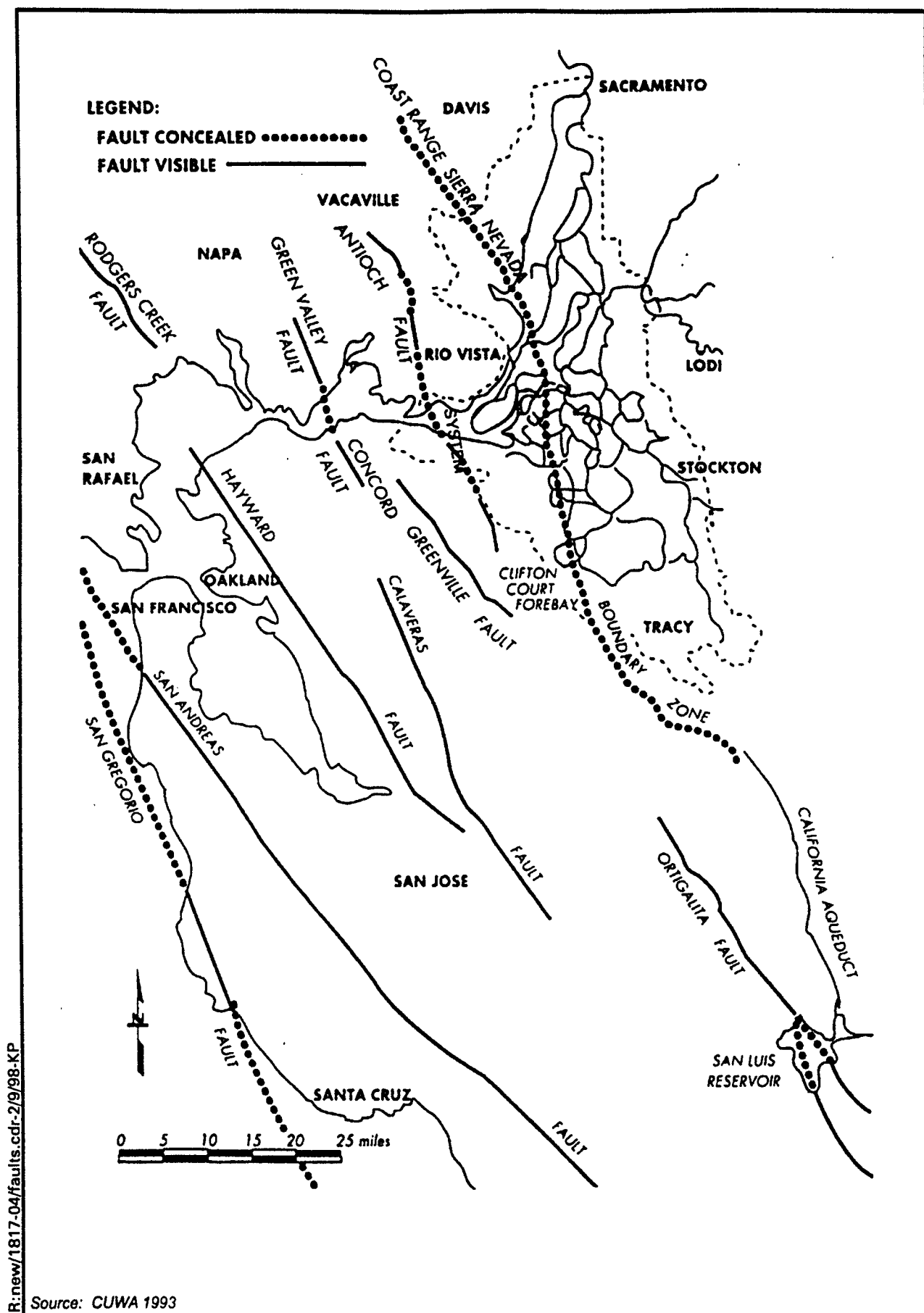


Figure 3. Faults within and near the Delta

This includes 80 to 90% of the area of organic and highly organic mineral soils, Sacramento River and San Joaquin River deltaic soils, and basin and basin rim soils. Most of the remaining soils of the Delta study area primarily support farmlands that have values of high statewide significance for the production of agricultural products. The major exceptions are in Suisun Marsh and the Yolo Bypass, where flooding is frequent, and in developed areas. There are minor exceptions in other smaller areas affected by frequent flooding, inadequate drainage, or high soil salinity.

The Delta soils that have been affected the most by agricultural development are the organic soils and highly organic mineral soils. These effects are brought about by the flood protection of levees and the lowering of water tables by pumps and drainage ditches in order to make production possible.

SOIL SUBSIDENCE

Subsidence of the Delta's organic soils and highly organic mineral soils continues to be a critical problem (Figure 4) and presents a serious threat to the long-term viability and use of the Delta islands. The rates of subsidence in the Delta are among the highest in the world. The average current rate is estimated to be about 1 inch per year (Rojstaczer and Deverel 1993). The apparent decline in the average subsidence rate has been attributed to the decreasing amount of readily decomposable organic matter in the Delta soils.

About 80% of subsidence has been attributed to biochemical oxidation of organic soil material (DWR 1982, NCRS 1989, and Rojstaczer et al. 1991) as a result of long-term drainage and flood protection. The highest rates of subsidence occur in the central-Delta islands, where organic matter content in the soils is highest.

SOIL SALINITY

Dissolved salts in irrigation water can lead to high soil salinity, an unfavorable condition for agricultural crop production. High soil salinity

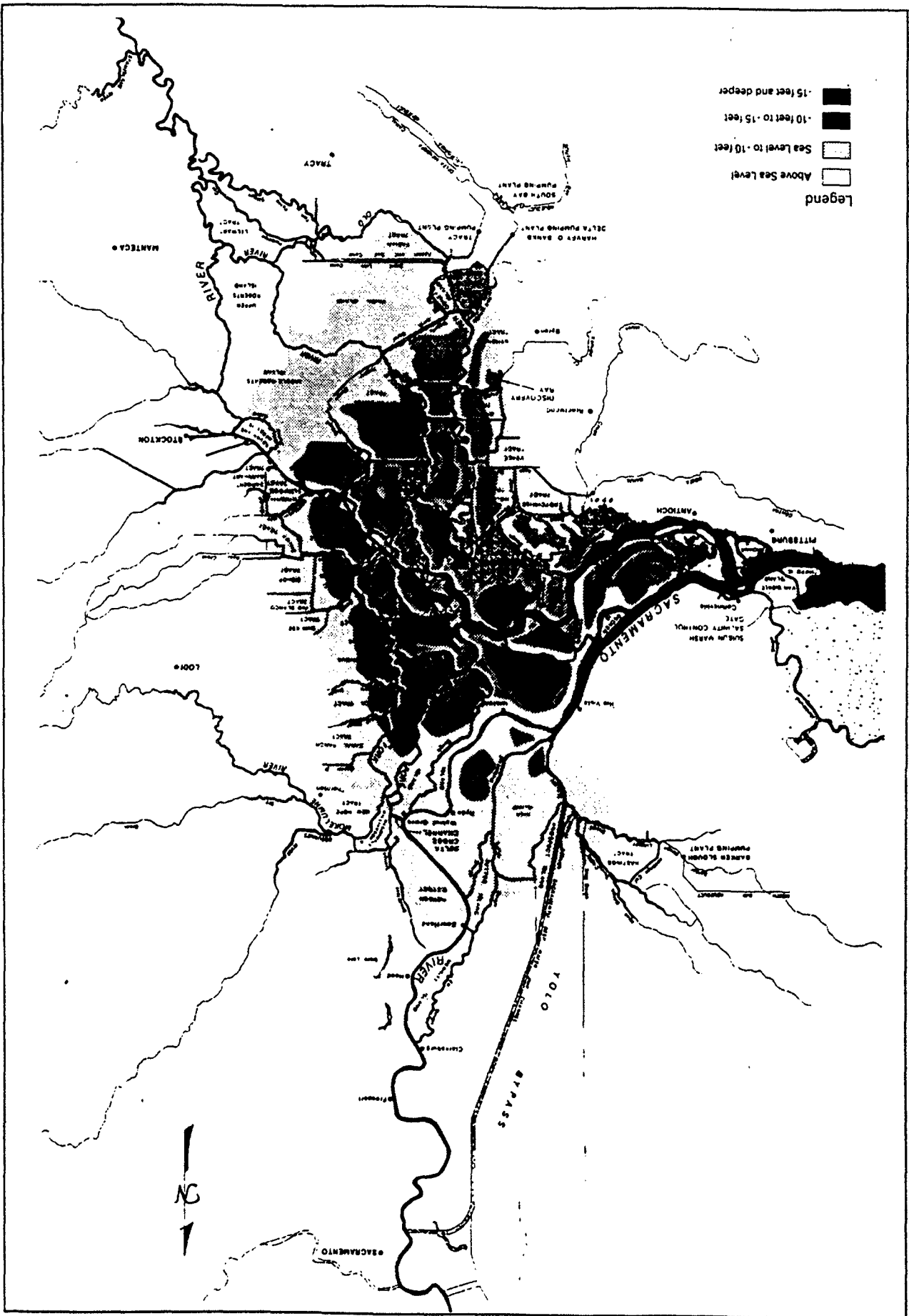
is an issue in several portions of the Delta, including the south-Delta area served by the South Delta Water Agency, the west-Delta area (primarily Sherman and Twitchell islands), and Suisun Marsh. North- and east-Delta areas receive relatively low-salinity water from the Sacramento River and east-side tributaries, and do not experience salinity problems.

The concentration of salinity in shallow groundwater and the salt mass contained in Delta soils are direct consequences of the quality of the irrigation water drawn from Delta channels. As a result, the management of soil salinity problems in the Delta is dependent on upstream and in-Delta water quality management practices. During low-flow periods, providing high-quality water to some parts of the Delta generally requires substantial releases of stored water from Central Valley Project (CVP) and State Water Project (SWP) reservoirs.

Current soil salinity problems in the area served by the South Delta Water Agency are tied to low freshwater flows and relatively high salt concentrations in the San Joaquin River. Farmers exercising riparian rights draw on this water source for crop irrigation. Transpiration and evaporation consume substantial amounts of the applied irrigation water. To manage the salinity problem, farmers flood their lands in spring with better-quality water to flush out accumulated salts. Consequently, the salinity of the return flows of drainage water is increased. As a result of low flows in some Delta channels, the drainage water is not effectively diluted by freshwater flows. This results in poor-quality water in the channels.

The west-Delta (primarily Sherman and Twitchell islands) is affected by salinity from a different source than is the south-Delta. In the west-Delta, tidal flows bring brackish water when freshwater outflows are low, further reducing the quality of irrigation water applied. The irrigation water quality for these west-Delta islands is primarily controlled by state water quality standards. During low outflow periods, these standards can be difficult to maintain.

Figure 4. Land Surface below Sea Level in the Delta



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High soil salinity is also an issue in Suisun Marsh. Suisun Marsh is naturally brackish from the influence of adjacent saline tidal waters and their influx into the marsh, but its salinity has increased as a result of reduced outflows of freshwater from the Sacramento River. The Plan of Protection for Suisun Marsh provides for marsh protection and mitigation for upstream diversions.

WIND EROSION

Recent soil surveys, including those conducted for Sacramento County (NRCS 1993a) and San Joaquin County (NRCS 1992), contain wind erodibility ratings for the soils. The Delta organic soils and highly organic mineral soils have wind erodibility ratings of 2 to 4 on a scale where 1 is most erodible and 8 is least erodible. The wind erodibility ratings of Delta soils are correlated to the amount of organic matter contained in them, with the most erodible soils being those having the highest percentages of organic matter content. The rate of wind erosion is estimated at 0.1 inch per year (NRCS 1989).

DELTA SEISMICITY

The primary seismic threat to the Delta is the threat of massive or widespread levee failures resulting from lateral displacement and deformation, with resultant breaching and/or mass settlement due to ground shaking and liquefaction of underlying soils. Finch (1992) analyzed the potential for earthquake-induced liquefaction in Delta levees. An analysis of levee materials showed that many levees included sandy sections with low relative density and high susceptibility to liquefaction. He concluded that the seismic risk to the Delta levees is high and increasing with time. The State of California has predicted failure of Twitchell Island levees under the Maximum Credible Earthquake for the area (Corps 1993).

SEDIMENTATION AND FLUVIAL EROSION IN THE DELTA

The great quantities of sediment transported by the rivers into the Delta and Bay move primarily

as suspended load. Of the estimated 5 million tons per year of sediment inflow into the Delta (Porterfield 1978), about 80% originates from the Sacramento and San Joaquin river drainages; the remainder is contributed by local streams. Estimates of the amount of sediment deposited in the Delta vary from 15% (Corps 1967) to 30% (Conomos 1976); the balance moves into the San Francisco Bay System or out through the water project facilities.

Sediment circulation within the Bay-Delta system is complex due to the numerous interconnected channels, tidal flats, and bays, within which the interaction of freshwater flows, tides, and winds produce an ever-changing pattern of sediments suspension and deposition. Pumping at the CVP and SWP Delta facilities alters this circulation of sediments within the system. In addition, higher water velocities induced in the channels by the pumping plants may cause erosion of the bed and banks.

The mechanics of sediment transport in either saline or tidally affected streams, such as the lower Sacramento River and the Delta, are even more complex than in freshwater streams. This complexity results from changes in flow velocity, flow direction, and water depth caused by the tides.

Erosion may occur when: (1) the velocity of flow in a channel is increased, (2) the sediment inflow to a channel in equilibrium is reduced, (3) pre-dominance of flow in one direction is altered in a channel that experiences reverse flows. The actual rate of erosion depends on the composition of the material on the bed and banks and on the amount of change in the factors listed previously.

Deposition is induced when conditions are the opposite of those favorable for erosion. The rate of deposition depends on the type and amount of sediment in suspension, the salinity, and the extent to which the transport capacity of the channel has been changed by reduction in flow velocity and channel size.

The Delta is primarily a depositional environment, but variations in water and sediment inflow result in both deposition and erosion. Increasing salinity causes the suspended load of clay and silt particles to form aggregates that settle and deposit more rapidly than the individual sediment particles. Deposition near Rio Vista may be caused by the convergence of the Sacramento River with the Sacramento Deep Water Ship Channel, forming a wider channel with resultant lower water velocities.

Flows induced by use of the Delta Cross Channel have affected the North Fork of the Mokelumne River by eroding a rather deep channel near New Hope. This erosion and the increased flow may have accelerated the need for riprap on the Mokelumne River levees. Also, it may have improved flood control conditions because of the increased channel capacity of the North Fork of the Mokelumne River. Delta Cross Channel flows that go down the South Fork pass through Dead Horse Cut and impinge on the Staten Island Levee at a right angle. There have been complaints about the erosion of the bank in this area for many years.

The discharges and velocities in the channels south of the San Joaquin River are influenced significantly by exports at the CVP and SWP pumping plants. Sediment deposition and gain from local drainage alter the amount and composition of the sediment transported in the channels. In addition, degradation or aggradation and widening or narrowing of certain channels may be occurring due to the higher velocities caused by pumping.

Finally, water carrying suspended sediment enters Clifton Court Forebay, within which a portion of this material is deposited (Arthur 1976). The rest is pumped into the Governor Edmund G. Brown California Aqueduct for conveyance southward to SWP service areas. In the case of the CVP, all of the suspended sediments enter the intakes and are pumped south.

According to the Resources Management Associates report (1983), substantial amounts of sediment are deposited in the Delta channels. Because tidal flow reversals occur in most of the Delta channels and the velocities fluctuate significantly in all channels, two types of channels exist with respect to erosion and deposition. Some channels experience deposition; others experience both deposition and erosion, depending on the phase of the tide. Changing tidal ranges and freshwater flows may alter the specifics of the situation in some of the channels.

Additional information on suspended sediment loads is included in the Supplement to this report.

Environmental Setting - Bay Region

HISTORICAL PERSPECTIVE

The Bay occupies a structural trough that formed during the late Cenozoic when it was part of a great drainage basin of the ancestral San Joaquin, Sacramento, and Coyote rivers (Cloern and Nichols 1985). The Bay was formed between 10,000 and 25,000 years ago by the melting of polar ice caps at the end of the fourth glacial period. As the ocean rose, it flooded the gap in the Coast Ranges formed by the Sacramento River, at what is now called the Golden Gate (Williams and Monroe 1970), and flooded inland river valleys forming San Francisco Bay, San Pablo Bay, and Suisun Bay.

CURRENT RESOURCE CONDITIONS

SOILS CONDITIONS

The sediments of the bay shallows are comprised of silty clay, clayey silt, and sand-silt-clay, while sand and silty sand cover the deeper areas of the Central Bay and San Pablo

Bay. Gravelly sands are found at the Golden Gate and grade seaward to a well sorted sand that covers most of the intercontinental shelf region of the Gulf of the Farallones (Cloern and Nichols 1985).

The Bay Region can be divided into four major landform types (each with characteristic soils): 1) basin floor/basin rim, 2) floodplain/valley land, 3) terraces, and 4) foothills and mountains. Basin lands consists of organic-rich saline soils adjacent to the Bay and poorly drained soils somewhat farther from the Bay. Valley land soils are generally found on gently sloping alluvial fans that surround the floodplain and basin lands and, along with floodplain alluvial soils, represent the most important agricultural group of soils in California. In the Bay area, most of the floodplain and valley land soils have been urbanized.

Terrace land soils are found along the southeastern edge of the San Francisco Bay area at elevation 5 to 100 feet above the valley land. Most of these soils are moderately dense soils of neutral reaction.

Soils of the foothills and mountains which surround the Bay are formed in place through the decomposition and disintegration of the underlying parent material. The most prevalent foothills soil group is that with a moderate depth to bedrock (20 to 40 inches), with lesser amounts of the deep depth (>40 inches) and shallow depth (<12 inches) to bedrock soil groups being present. Moderate depth soils are generally dark colored, fairly high in organic matter, and constitute some of the best natural grazing lands of the state. Deep soils occur in the high rainfall zones at the higher elevations in the Coast Range. They generally support the forested lands in the Bay Region and are characterized by acid reaction and depths to bedrock of 3 to 6 feet. Shallow soils occur in the medium-to-low rainfall zone. They are loamy in character and are used principally for grazing.

SAN FRANCISCO BAY SEISMICITY

Major earthquake activity has centered along the San Andreas Fault zone, including the great San Francisco earthquake of 1906. Since that earthquake, there have been four events of magnitude 5.0 (Richter scale) or greater in the Basin. The San Andreas fault remains fairly active with evidence of recent slippage along the fault (SWRCB 1975). (Refer to Figure 3.)

SEDIMENTATION AND EROSION IN SAN FRANCISCO BAY

The major source of suspended sediment in the Bay is outflow from the Delta. Approximately three-quarters of the suspended sediment enters the Bay with the high winter and early spring flood flows. The highest suspended sediment and turbidity levels occur during these periods. Although much of the suspended sediment begins to aggregate at the salinity gradient and deposit in the shallow areas of Suisun and San Pablo bays; however, the high seasonal flows can transport incoming sediment as far as the Central and South bays (Kelley and Tippets 1977).

Sediments deposited in the more shallow regions are resuspended by wave and wind action. Sediments in the deeper regions are scoured and suspended by tidal currents. Finer resuspended sediments are transported and deposited in the ocean or other areas within the Bay where resuspension forces are low, leaving coarser sediments on the bottom (Krone 1976).

Approximately 15 times as much material is resuspended each year as actually enters the Bay (Corps 1975). Resuspension of sediment is the most important process in maintaining turbidities in the Bay from late spring through the fall (Kelley and Tippets 1977).

Sacramento River Region

HISTORICAL PERSPECTIVE

The Sacramento River drains over 21,000 mi² (below the Feather River confluence), producing an annual average flow of 19,000 cfs. The upper watersheds of the Sacramento River Region include the drainages above Shasta Reservoir, the Clear Creek drainage basin west of Redding, the upper Colusa watershed and Cache Creek watersheds west of the valley, and the Feather River and American River watersheds east of the valley. These watersheds are described in detail in the Surface Water Technical Report.

Hydraulic mining on the western slopes of the Sierra Nevada between 1853 and 1884 dramatically increased the sediment budgets of central Sierran streams and rivers. The addition of abundant coarse material overwhelmed the capacity of the rivers, resulting in temporary storage of the sediment in channels and floodplains and widespread flooding of the Central Valley towns and farms. Since the end of hydraulic mining more than 100 years ago, most rivers have reestablished their original gradients, aided by trapping of the mining sediment behind dams and scouring of the channels promoted by levees built along the rivers.

The hydrology of the Sacramento River has been profoundly altered by reservoir construction. At Red Bluff, the average annual floodflow was 121,000 cfs before construction of Shasta Dam (1879 to 1944), and 79,000 cfs after (1945 to 1993). The 10-year flood has been reduced from 218,000 cfs to 134,000 cfs. This has reduced the energy available to transport sediment in the Sacramento River. Moreover, the sediment supply to the river has been reduced by sediment trapping in reservoirs; by mining of sand and gravel from channel beds; and from artificial protection of river banks, the erosion of which had supplied sediment to the channel.

Rates of bank erosion and channel migration have declined since 1946, presumably due to changes in flow and blockage of upstream sediment supply as a result of Shasta Dam, and due to the construction of downstream bank protection projects (Brice 1977, Buer 1984, Corps 1986, and WET 1988). The channel sinuosity (ratio of channel length to valley length) also has decreased.

CURRENT RESOURCE CONDITIONS

SOILS DESCRIPTION

Table 1 summarizes the land soils for the four physiographic areas of the Sacramento River Region. Valley land and floodplain alluvial soils make up some of the best agricultural land in the state. Valley basin lands consist of poorly drained soils, and saline and alkali soils in the valley trough and on the basin rims. Areas above the Central Valley floor consist of terrace and upland foothills, and soils in the foothills and mountains. Overall, these soils are not as productive as the valley land and valley basin land soils. Without irrigation, these soils are primarily used for grazing and timberland; however, with irrigation, additional crops can be grown.

The upper watersheds of the Sacramento River Region area mainly drain foothill soils. These soils are found on the hilly to mountainous terrain surrounding the Sacramento Valley and are formed in place through the decomposition and disintegration of the underlying parent material. The most prevalent foothill soil group is that with a deep depth (>40 inches) to bedrock, shallow depth (<20 inches) and very shallow depth (<12 inches) to bedrock. Additional information on Sacramento River Region soil characteristics is found in the Supplement to this report.

GEOLOGIC CONDITIONS

The geologic provinces composing the Sacramento River Region include the Klamath Mountains, the Coast Ranges, The Cascade

Range/Modoc Plateau, the Sierra Nevada, and the Central Valley provinces (Figure 1).

A description of the geologic provinces in the Sacramento River Region is found in the Supplement to this report.

GEOMORPHOLOGIC CONDITIONS

Downstream of Red Bluff, the Sacramento River flows within a meander belt of recent alluvium. The channel's configuration is the result of geomorphic processes, the influence of geologic structures, and human alterations. The river is characterized by an active channel, with point bars on the inside of meander bends, and flanked by active floodplain and older terraces. While most of these features consist of easily erodible, unconsolidated alluvium, there are also outcrops of resistant, cemented alluvial units such as the Modesto and Riverbank formations (Helley and Harwood 1985).

Within the channel itself, the bed is composed of gravel and sand (less gravel with distance downstream), and point bars are composed of sand. The bottomlands flanking the channel consist of silts and sands (deposited from suspended load in floodwaters) commonly overlying channel gravels and sands. Higher, older surfaces consisting of (often cemented) Pleistocene deposits also are encountered.

The river channel migrates (maintaining roughly constant dimensions) across the floodplain to the limits of the meander belt, constrained only by outcrops of resistant units or artificial bank protection. As meander bends grow, they may become unstable and form cutoffs.

Since construction of Shasta Dam in the early 1940s, flood volumes on the river have been reduced, which reduces the energy available for sediment transport. Straightening and reduced meander migration rate of the river may be associated with flow regulation due to Shasta Dam. The reduced migration rate has ecological consequences because the diversity of riparian and aquatic habitats are directly related to the processes of bank erosion, point bar building, and overbank deposition. These processes

create fresh surfaces for riparian establishment, resulting in a mosaic of different-aged vegetation, and also contribute to the complexity of in-channel habitat and shaded bank cover (California State Lands Commission 1993).

The reduction in active channel dynamics is compounded by the physical effects of riprap bank protection structures, which typically eliminate shaded bank habitat and associated deep pools, as well as halting the natural processes of channel migration.

Sediment loads in the streams draining the upper watersheds have been artificially increased due to past and current logging and grazing practices. Both practices remove soil-stabilizing vegetation, create preferential drainage ways, and promote localized soil compaction. Erosive overland flow is enhanced by the loss of vegetation and compacted soils. Larger amounts of sediment are delivered to the streams from increased rates of soil erosion and from enhanced rates of mass movement, such as landslides. During high runoff events, the sharp increases in sediment yields can lead to widespread channel aggradation, which in turn, can lead to lateral migration of the channels and increased rates of landsliding.

Where reservoirs have been created by dams, most of the sediment is trapped behind the dam and during the life of the reservoir will not be transported downstream of the dam. Where such sediment traps are not in place, the sediment load will be transferred downstream, where it can cause adverse effects to the resources and along the waterways.

Physiographic Region	Location	Soil Texture	Non-Irrigated Crops	Irrigated Crops	Additional Features
Valley Land					
Alluvial soils	Alluvial fans and low terraces in the Sacramento Valley	Sandy loam - loam		Alfalfa, vegetables, fruits, sugar beets, cotton	
Valley Basin					
Imperfectly drained soils	Sacramento-San Joaquin Valley Trough	Clays	Pasture	Pasture, rice, cotton	High water table
Terrace Land					
Brown, neutral soils	West-side Sacramento Valley	Loam	Pasture	Pasture	
Red-iron hardpan soils	East-side Sacramento Valley	Sandy loam - loam, hardpan	Alfalfa, grains, pasture	Fruits	Hardpan layer present
Upland Soils					
Shallow depth to bedrock	Foothills surrounding the Central Valley	Loam - clay loams	Pasture		Tilled soils prone to erosion
Deep depth to bedrock	Higher elevations of the Sierra Nevada, Klamath, Mountains, and Coast Ranges	Loam - clay loams	Timberland		Granitic soils on steep slopes highly susceptible to erosion
SOURCE: Adapted from University of California 1980.					

Table 1. Sacramento River Region - Soils Summary Table

SOIL SUBSIDENCE

Land subsidence in the Sacramento Valley is localized and concentrated in areas of groundwater-pumping-induced overdraft. Land subsidence had exceeded 1 foot in 1973 in two main areas in the southwestern part of the valley, near Davis and Zamora; additional subsidence since then, however, has not been reported. In general, use of groundwater for irrigation is much less extensive in Sacramento Valley than in the San Joaquin Valley because of greater surface water availability. In addition, greater natural recharge in this area relative to the San Joaquin Valley results in less severe groundwater level declines.

Additional information on groundwater and associated land subsidence may be found in the Groundwater Technical Report.

SEISMICITY

The Great Valley thrust fault system forms the boundary between the Coast Ranges and the Sacramento and San Joaquin Valleys. This fault system is capable of earthquakes up to magnitude 6.8 along the west side of Sacramento Valley. The Mendocino Range west of the valley is mainly subject to seismicity from northwest-trending faults associated with the right-lateral strike-slip San Andreas Fault System.

The mapped active faults of this system that are most likely to affect the upper watersheds west

of the Sacramento Valley are the Green Valley, Hunting Creek, Bartlett Springs, Round Valley, and Lake Mountain faults. These faults lie along a 150-mile long northwest-trending zone of seismicity 10 to 45 miles west of the Sacramento Valley that extends from Suisun Bay past Lake Berryessa and Lake Pillsbury to near the latitude of Red Bluff. These faults are capable of earthquakes up to magnitude 7.1.

Active faults likely to affect the upper watersheds northeast of the Sacramento Valley, in the drainages upstream of the Shasta Reservoir, include the Mayfield-MacArthur-Hat Creek Faults, 25 to 85 miles north of Lake Almanor, the Gillem-Big Crack Faults near the California-Oregon border southeast of Lower Klamath Lake, and the Cedar Mountain Fault southwest of Lower Klamath Lake. These faults are part of the Sierra Nevada-Great Basin dextral shear zone and are capable of earthquakes up to magnitude 7.0. Farther northeast, the Likely Fault is judged capable of a magnitude 6.9 earthquake, and in the northeast corner of the state the Surprise Fault is capable of a magnitude 7.0 earthquake.

Active faults likely to affect the upper watersheds east of the Sacramento Valley include the Indian Valley Fault southeast of Lake Almanor and the Honey Lake Fault Zone east of Lake Almanor, which is capable of a magnitude 6.9 earthquake. Surface rupture occurred in 1975 along the Cleaveland Hill Fault south of Lake Oroville. The Foothills Faults System, which border the east side of the Sacramento and San Joaquin Valley, is judged to be capable of a magnitude 6.5 earthquake.

INSTREAM GRAVEL MINING

Aggregate mining occurs within many streams in the western foothills of California. Generally, these rivers or streams are located along natural troughs of gravel and sand deposits. Unconsolidated gravels and slates also are mined in the lower foothills of the Sierra Nevada. Because of their convenient proximity to the ground surface and their location on flat land, these deposits have been mined for many

years. The aggregates are primarily used for building and road construction materials.

Instream gravel mining causes significant water quality and habitat problems due to the increased release of sediments in the river as well as the removal of soils in the areas of mining activities.

WIND EROSION

Soil erodibility, local wind erosion climatic factors, soil surface roughness, width of field, and quantity of vegetative coverage affect the susceptibility of soils to wind erosion.

Wind erosion renders the soil more shallow, and can remove organic matter and needed plant nutrients. Also, blowing soil particles can damage plants, particularly young plants. Blowing soils also can cause offsite problems such as reduced visibility and increased allergic reaction to dust.

Wind erosion from cultivated and uncultivated soils may result in fine particles remaining airborne for considerable periods of time.

WATER EROSION

There are several types of water-induced soil erosion. Some factors that influence the erodibility of soils include land slope, surface texture and structure, infiltration rate, permeability, particle size, and the presence of organic or other cementing materials.

The Universal Soil Loss Equation is widely used to predict the severity of erosion from farm fields. Six factors that determine the long-term average annual soil loss for a given location are the long-term average rainfall-runoff erosivity factor, soil erodibility index, slope length factor, slope gradient factor, soil cover factor, and an erosion control practice factor. The detailed nature of this estimation prevents extrapolation to regional level. The NRCS (formerly the SCS) soil surveys provide detailed information on soil erosion potential by soil mapping units.

Environmental Setting - San Joaquin River Region

HISTORICAL PERSPECTIVE

The San Joaquin River drains 13,500 mi² along the western flank of the Sierra Nevada and eastern flank of the Coast Ranges, producing an average flow of 4,600 cfs near Vernalis. The San Joaquin has three major tributaries that drain the Sierra Nevada. In downstream order, they are the Merced (drainage area 1270 mi², average flow 1,350 cfs), Tuolumne (1,884 mi², 2,254 cfs), and Stanislaus rivers (980 mi², 1,400 cfs). Precipitation is predominantly snow above 1,200 meters in the Sierra Nevada, and rain in the middle and lower elevations of the Sierra Nevada and Coast Ranges. As a result, the natural hydrology reflects a mixed runoff regime of summer snowmelt and winter-spring rainfall runoff. Another major river, the Mokelumne, enters the eastern Delta along with minor tributaries (including the Cosumnes and Calaveras rivers), joining the San Joaquin River prior to its confluence with the Sacramento. The drainage area of the Mokelumne River is 660 mi².

The hydrology of the San Joaquin River and its tributaries has been profoundly altered by dam construction and surface water diversions. So much water is diverted from Friant Dam that the mainstem San Joaquin River now goes dry at Gravelly Ford, some 30 miles downstream, except during periods of high flow. Storage of flood waters behind Friant Dam has resulted in a decline in flood magnitudes on the mainstem San Joaquin River. Similar reductions have occurred on the major tributaries, such as the Merced River, where the 10-year flood decreased from a pre-1925 flow of 22,900 cfs to 8,300 cfs after 1967, following construction of the Exchequer and New Exchequer dams (Kondolf et al. 1996). This has reduced the energy available to transport sediments.

Sediment supply to the river system has been reduced by catchment and trapping in reservoirs; mining of sand and gravel from

channel beds; and from artificial protection of river banks, the erosion of which had supplied sediment to the channel.

The upper watersheds of the San Joaquin River Region include the West San Joaquin upper watershed west of the San Joaquin Valley, the northern and southern San Joaquin River watersheds, and the Kings River watershed, along the east side of the San Joaquin Valley. These upper watersheds are described in detail in the Surface Water Technical Report.

The upper watershed area on the west side of the San Joaquin River Valley drains the east side of the Coast Range Province, while the upper watersheds on the east side of the valley drain the southern part of the Sierra Nevada Province.

The floodplains of the San Joaquin River and tributaries have been extensively modified for agricultural development, with elimination of many acres of slough and side channel habitat (Kondolf et al. 1996).

Gravel extraction has been both extensive and intensive from the upper mainstem and the major tributaries. The combined effects of sediment trapping by upstream reservoirs and, to a lesser extent, reduced bank erosion from riprapping have resulted in a condition of sediment-starvation. For example, on the Merced River an estimated 150,000 to 300,000 tons of sediment have been trapped behind the Exchequer Dams since 1926, and 7 to 14 million tons of sand and gravel have been excavated from the channel and floodplain since the 1950s (Kondolf et al. 1996).

In addition, excavation of pits for aggregate production has directly transformed many reaches of the San Joaquin River and its tributaries from flowing rivers to quiescent lakes. Some of the pits have been excavated directly in the active channel, others have been excavated on the adjacent floodplain but captured by the channel. The Merced River flows through at least 15 pits, seven of which are captured floodplain pits. These pits warm up in summer and provide habitat for exotic

species such as largemouth and smallmouth bass, which prey extensively on juvenile salmon. The California Department of Fish and Game (DFG) estimated that 70% of the juvenile salmon migrating seaward through the Tuolumne River in 1987 were lost to predation, mostly in these old gravel pits (EA Engineering 1992).

Increasing soil salinity has been recognized as a problem in the San Joaquin Valley since the 1800s. The first problems were encountered between 1870 and 1915, when a rapid increase in irrigated acreage coincided with increasingly poor drainage (due to elevated shallow groundwater table levels) and elevated salinity levels in the western and southern portions of the San Joaquin Valley. Between 1915 and the 1930s, an agricultural boom and formation of irrigation districts elevated attention to drainage and salinity problems to district levels. It was not until the 1920s that deep well pumping lowered the water table below the root zone of plants on the east side of the valley. Dry-farming practices were replaced with irrigated agriculture on the west side in the 1940s, leading to the spreading and worsening of drainage problems on the west side of the valley and near the valley trough in the 1950s.

As a result of heavy pumping, groundwater levels declined by more than 300 feet in certain areas during the 1940s and 1950s. Imported surface water supplies in the 1950s and 1960s reduced reliance on groundwater and helped control the rapid rate of groundwater level decline. Groundwater level declines that occurred in many areas of the Tulare Lake Region have resulted in significant land subsidence over large areas. Significant historical land subsidence caused by excessive groundwater pumping has been observed in the Los Banos-Kettleman City area (northwestern portion of the Tulare Lake Region), the Tulare-Wasco area, and the Arvin-Maricopa area.

Additional information on groundwater and associated land subsidence may be found in the Groundwater Technical Report.

CURRENT RESOURCE CONDITIONS

SOILS DESCRIPTION

In the San Joaquin River Region, soils are divided into four physiographic regions, as summarized in Table 2. These physiographic regions are the same as those described for the Sacramento River Region: valley, valley basin, terrace, and upland. Characteristic soils found in these physiographic regions are described in the Supplement at the end of this report.

The upper watersheds of the San Joaquin Valley area mainly drain foothills soils (Figure 6.3.1-2) which are found on the hilly to mountainous topography surrounding the San Joaquin Valley. Moderate depth to bedrock (20-40 inches) soils occur on both sides of the northern part of the San Joaquin Valley where the annual rainfall is intermediate to moderately high. Deep (>40 inches) soils are the important timberlands of the area and occur in the high rainfall zones at the higher elevations in the mountains east of the valley. Shallow (<20 inches) soils, used for grazing, occur in the medium-to-low rainfall zone at lower elevations on both sides of the valley. Very shallow (<12 inches) soils are found on steep slopes, mainly at higher elevations, and are not useful for agriculture, grazing, or timber because of their very shallow depth, steep slopes, and stony texture.

GEOLOGIC CONDITIONS

The geologic provinces encompassing the San Joaquin River Region include the Coast Ranges, Central Valley, and Sierra Nevada provinces.

These provinces also are discussed in the Supplement to Geology & Soils.

GEOMORPHOLOGIC CONDITIONS

The mainstem San Joaquin River meanders within a meander belt of recent alluvium. The channel's configuration is the result of geomorphic processes, the influence of geologic structures, and human alterations. The river is characterized by an active channel, with point

bars on the inside of meander bends, flanked by an active floodplain and older terraces. While most of these features consist of easily erodible, unconsolidated alluvial deposits, there are also outcrops of resistant, cemented alluvial units such as the Modesto and Riverbank formations.

Within the channel itself, the bed is composed of gravel and sand (less gravel with distance downstream), and point bars are composed of sand. The bottomlands flanking the channel consist of silts and sands (deposited from suspended load in floodwaters) commonly overlying channel gravels and sands. Higher, older surfaces consisting of (often cemented) Pleistocene deposits also are encountered.

The river channel migrates (maintaining roughly constant dimensions) across the floodplain to the limits of the meander belt, constrained only by outcroppings of resistant units or artificial bank protection. As meander bends grow, they may become unstable and form cutoffs, leaving oxbow lakes like those visible along lower reaches of the mainstem.

Sediment loads in streams draining the upper watersheds of the San Joaquin River Region are similar to those described in the Sacramento River Region.

SOIL SUBSIDENCE

After nearly two decades of little or no land subsidence, significant land subsidence recently has been detected in the San Joaquin Valley due to increased groundwater pumping during the 1987 to 1992 drought. Land subsidence occurring between 1984 and 1996 was reported along the Delta-Mendota Canal.

Additional information can be found in the Groundwater Technical Report.

SEISMICITY

In the San Joaquin River Region, the Great Valley thrust fault system forms the boundary between the Coast Ranges and the west boundary of the San Joaquin Valley. This fault system is capable of earthquakes up to

magnitude 6.7 along the west side of San Joaquin Valley.

The Diablo Range west of the valley is mainly subject to seismicity from northwest-trending faults associated with the right-lateral strike-slip San Andreas Fault System.

The mapped active faults of this system that are most likely to affect the upper watersheds west of the San Joaquin Valley are the Ortigalita Fault and the Greenville-Marsh Creek Fault. These faults lie along northwest-trending zones of seismicity 5 to 20 miles west of the San Joaquin Valley and each is capable of earthquakes up to magnitude 6.9.

Active faults likely to affect the upper watersheds east of the San Joaquin Valley include the Foothills Fault System and major faults along the east margin of the Sierra Nevada. The Foothills Fault System, which borders the east side of the northern part of the San Joaquin Valley, is judged to be capable of a magnitude 6.5 earthquake. Active faults along the east margin of the Sierra Nevada include the Owens Valley Fault, which ruptured in a magnitude 7.6 earthquake in 1872 and is within the Sierra Nevada Fault Zone. Seismic activity along this fault zone can significantly affect the upper watersheds that drain to the San Joaquin Valley.

Active faults likely to affect the upper watersheds at the southern end of the San Joaquin Valley, include the White Wolf Fault, which ruptured in 1952 with a magnitude 7.2 earthquake, the Garlock Fault, capable of the a magnitude 7.3 earthquake, and several smaller faults 10 to 30 miles north of the White Wolf Fault.

SOIL SALINITY

Soil salinity problems occur primarily in the western and southern portions of the San Joaquin Valley. Most soils in this region were derived from marine sediments of the Coast Ranges, which contain salts and potentially toxic trace elements such as arsenic, boron, molybdenum, and selenium. Soil salinity

Physiographic Region and Soil Type	Location	Soil Texture	Non-Irrigated Crops	Irrigated Crops	Additional Features
Valley Land					
Alluvial soils	Alluvial fans and low terraces in the San Joaquin Valley	Sandy loam - loam		Alfalfa, vegetables, fruits, sugar beets, cotton	
Aeolian soils	Portions of Stanislaus, Merced, and Fresno counties	Sands - loamy sand		Fruits, alfalfa	Prone to wind erosion; soils deficient in plant nutrients
Valley Basin					
Imperfectly drained soils	Sacramento-San Joaquin Valley Trough	Clays	Pasture	Pasture, rice, cotton	High water table
Saline/alkaline soils	West side of San Joaquin Valley	Clay loam - clay	Pasture	Grains, rice, cotton	Leaching required to remove excess salts
Terrace Land					
Brown, neutral soils	Southeast side San Joaquin Valley	Clay	Pasture	Pasture	
Red-iron hardpan soils	East-side San Joaquin Valley	Sandy loam - loam hardpan	Alfalfa, grains, pasture	Fruits	Hardpan layer present
Upland					
Shallow depth to bedrock	Foothills surrounding the Central Valley	Loam - clay loams	Pasture		Tilled soils prone to erosion
Moderate depth to bedrock	East side Merced and Stanislaus counties	Sandy loam - clay loam	Pasture		
Deep depth to bedrock	Higher elevations of the Sierra Nevada, Klamath Mountains, and Coast Ranges	Loam - clay loams	Timberland		Granitic soils on steep slopes highly susceptible to erosion
SOURCE: Adapted from University of California 1980.					

Table 2. San Joaquin River Region - Soils Summary Table

problems in the San Joaquin Valley have been, and continue to be, intensified by poor soil drainage, insufficient water supplies for adequate leaching, poor quality (high-salinity) applied irrigation water, high water tables, and an arid climate.

Despite efforts to develop plans to deal with the problems, drainage and soil salinity problems continue to persist in the San Joaquin Valley. A 1984 study (Backlund and Hoppes) estimated that about 2.4 million of the 7.5 million acres of irrigated cropland in the Central Valley were adversely affected by soil salinity. These saline soils generally exist in the valley trough and along the edges on both sides of the San Joaquin Valley, primarily on the west side.

SELENIUM CONCENTRATIONS

Soil selenium is primarily a concern on the west side of the San Joaquin Valley. When soils on the west side are irrigated, selenium (along with other salts and trace elements) dissolves and leaches into the shallow groundwater. Figure 5 shows selenium levels in the top 12 inches of soil as determined by a survey in the mid 1980s. Soils derived from the Sierra Nevada on the east side of the valley are less salty due to their granitic origins and contain much less selenium. Over the past 30 to 40 years of irrigation, soluble selenium has been leached from the soils into the underlying shallow groundwater aquifers (SJVDP 1990).

Refer to the Groundwater Technical Report for additional information on soil selenium.

SWP & CVP Service Areas Outside the Central Valley

A description of the soils and geomorphologic conditions of the SWP and CVP Service Areas Outside the Central Valley was omitted from this report because no impacts on these resource areas are expected as a result of any of the Program alternatives.

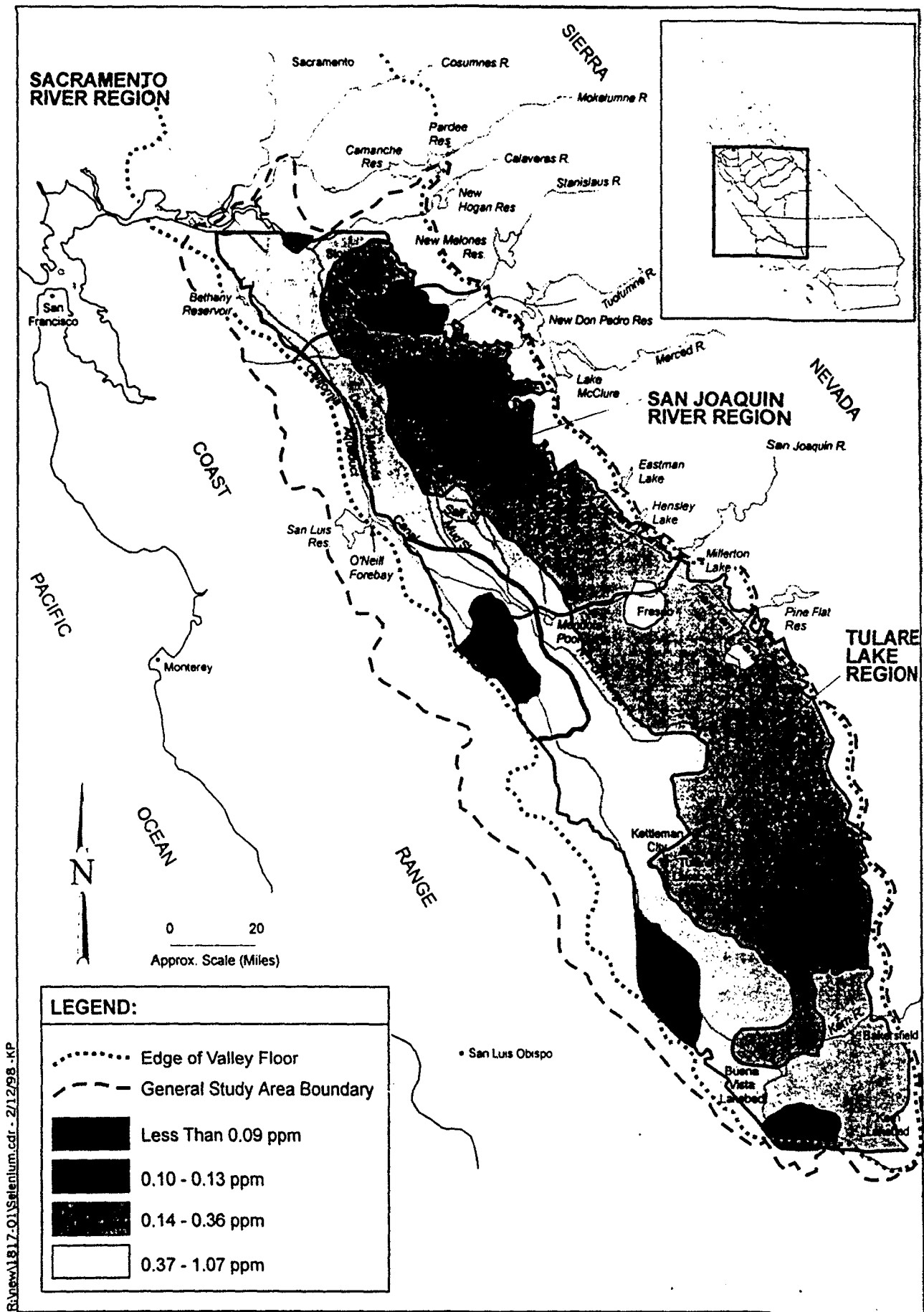


Figure 5. Selenium Concentrations in San Joaquin Valley Soils

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**TECHNICAL REPORT
AFFECTED ENVIRONMENT**

**SUPPLEMENT TO GEOLOGY & SOILS
DRAFT**

March 1998



SUPPLEMENT TO GEOLOGY & SOILS

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SUPPLEMENT TO GEOLOGY & SOILS

Delta Region

SOILS DESCRIPTION

The soils of the study area vary primarily as a result of differences in climate, parent material, biologic activity, topography and time. For the purposes of this discussion, the soils are divided into five general soil types:

- **Delta organic soils and highly organic mineral soils.** Organic and highly organic mineral soils are characterized as being level or nearly level, deep, and poorly or very poorly drained, and are formed from a combination of decayed plant materials and mineral sediments. The soils, which are generally protected behind natural or man-made levees, lie below sea level. They comprise most of the Delta island soils and the more saline soils underlying Suisun Marsh.
- **Sacramento River deltaic soils.** Sacramento River deltaic soils are characterized as being nearly level, deep, and somewhat poorly to very poorly drained. They are coarser textured mineral soils formed in part from hydraulic mining sediments. Some overlie layers of peat.
- **San Joaquin River deltaic soils.** San Joaquin River deltaic soils are characterized as nearly level, deep, and poorly drained. They consist of fine-textured mineral soils overlying more coarsely textured deposits.
- **Basin and basin rim soils.** Basin and basin rim soils are characterized as nearly level, deep, and moderately well to poorly drained. They are fine-textured to moderately fine-textured, and include some alkali and saline soils.
- **Moderately well- to well-drained valley, terrace, and upland soils.** Valley soils are level to gently sloping, deep, moderately well- to well-drained, and include soils formed in aeolian sand deposits, alluvial plain and alluvial fan deposits, and interfan basins. Terrace soils are gently sloping to undulating, deep, and moderately well- to well-drained. Upland soils are rolling to moderately steep, moderately deep to deep, and well drained.

The Delta study area contains primarily farmlands with the appropriate physical and chemical soil characteristics, growing season, and moisture supply necessary to qualify as prime farmlands. This includes 80 to 90% of the area of organic and highly organic mineral soils, Sacramento River and San Joaquin River deltaic soils, and basin and basin rim soils. Most of the remaining soils of the Delta study area primarily support farmlands that have values of high statewide significance for the production of agricultural products. The major exceptions are in Suisun Marsh and the Yolo Bypass, where flooding is frequent, and in developed areas. There are minor exceptions in other smaller areas affected by frequent flooding, inadequate drainage, or high soil salinity.

The Delta soils that have been affected the most by agricultural development are the organic soils and highly organic mineral soils. These soils began to oxidize and subside when they were first drained, and are currently subsiding at a rate of 1 or more inches a year (Rojstaczer et al. 1991; Rojstaczer and

Deverel 1993). In the 100-plus years since Delta reclamation began, some of the organic and highly organic mineral soils of the Delta have subsided as much as 20 feet. As a result of this subsidence, a large part of the Delta now lies below sea level. (Figure 4 in the technical report provides an illustration of subsidence.)

SEDIMENTATION AND EROSION IN THE DELTA

Over 90% of the sediment that enters the Delta is suspended sediment (Conomos & Peterson 1976) composed primarily of rock particles (80 to 97%); the remainder is living and detrital organic matter. More than 80% of the sediment load is transported in winter. These suspended sediments are very fine particles of clay and silt capable of forming aggregates when the salinity of the suspending water increases. These aggregates settle much more rapidly than the individual sediment particles; thus increasing salinities and/or reductions in flow velocities accelerate the rates of sediment deposition (De Groot et al. 1984).

Sediment erosion and overland transport conditions are influenced by precipitation, soil saturation, vegetative cover, and land use practices in the watershed. Each drainage channel has unique geometry; its suspended load and bedload characteristics are determined by flow, salinity, and sediment characteristics, such as grain size. Other water quality constituents, human activities, and infrastructure are among the many additional factors that also affect sediment transport (De Groot et al. 1984).

When streams discharge to tidal waters, changes in the tide affect where deposition will occur. A stream transporting some sediment sizes at its full ability will begin to deposit some particles of these sizes where the stream is first slowed by the effect of the ocean level. The place of this first deposition may vary several miles and depends on whether the flow is affected by high or low tide. Thus, along an appreciable reach of tidal stream, sediment deposition may be intermittent. Also, some sediments deposit slowly at low tide and much faster at high tide. Of course, the amount and site of deposition also vary with the discharge of the stream. If the streamflow is low, some fine sediment may even be carried back upstream while the tide is rising and be deposited before downstream flow begins again. Conversely, some fine sediment may be carried far out into the ocean or bay by the stream current, especially during floods (Graves 1977).

Erosion in channels may cause:

- Bank or levee instabilities.
- A drop in water surface elevation, which may affect pumping heads and the tidal incursions.
- Additional sediments to be suspended in the water volume, thereby increasing turbidities and causing accelerated deposition downstream.
- Flow changes in other channels as a result of altered flow distribution.

Increased sediment concentrations in the water may:

- Affect water quality by altering the nutrient and toxicant levels in the water and by reducing the penetration of sunlight, also affecting benthic conditions and dependent biological productivity. These effects may be beneficial or detrimental depending on the changes.

- Increase the amount of sediments in the water exported. This may cause problems in the aqueducts and points of water release.

Deposition in the channels may cause:

- Reduction in capacity to transport water, which may result in levee instability and flooding.
- Clarification of waters and increased light penetration, which may cause more rapid growth of algae.
- Flow diversions and altered tidal incursions.
- Reduced capacity in forebays.
- A reduction in channel depth, affecting navigable waterways.
- Increased costs for dredging in boat harbors and navigable waterways.

Resources Management Associates (1983) and the California Department of Water Resources (DWR) evaluated several data sources to obtain an indication of sediment transport conditions in Delta channels. The review revealed the following:

Sediment enters the Delta from the:

- Sacramento River,
- San Joaquin River,
- Lesser streams and local drainages, and
- Bay flood (incoming) tides.

Sediment is lost from the Delta by:

- Bay ebb (outgoing) tides;
- Pumping of export water; and
- Dredging, unless materials are returned to the fluvial system.

As shown in Table S-1, the average annual suspended sediment load was 2,407,862 tons/year (for the period 1957 to 1980) in the Sacramento River, and 310,073 tons/year (for the period 1960 to 1981) in the San Joaquin River. In addition to the suspended load transported into the Delta, it is estimated that about 345,250 tons/year of bed load is transported by the Sacramento River, and 46,500 tons/year by the San Joaquin River. The annual average total sediment loads are 2,753,112 tons/year for the Sacramento River and 356,573 tons/year for the San Joaquin River. Local drainage and direct runoff into the channels provide the rest of the sediment inflow to the Delta. Estimates of total sediment inflow from all sources vary from 4.5 to 5.2 million tons/year.

The bed material in the Sacramento River near Sacramento is medium sand, coarse sand, and fine sand, in order of occurrence. Progressing downstream, the fraction of fine sand increases, with a decrease in coarse sand. The material brought in by the San Joaquin River is finer sediment. Grab samples from Delta channels indicate that the surficial sediments are composed primarily of silt, silty sand, and, in areas of lower water velocity, clayey silt. The embayments, sloughs, and backwater areas in the west-Delta contain more clay, because the salinity in these areas reaches the flocculating concentration of 1 to 2 gm/L (De Groot et al. 1984).

Sacramento River at Freeport			San Joaquin River at Vernalis	
Water Year	Discharge (cfs-day)	Sediment Load (tons)	Discharge (cfs-day)	Sediment Load (tons)
1957	6,649,750	1,472,218	727,079	+
1958	12,572,290	4,947,900	3,053,420	+
1959	5,926,540	1,726,335	626,967	+
1960	5,362,340	1,752,738	277,237	45,608
1961	5,745,260	1,943,117	220,419	23,532
1962	6,263,300	1,659,850	749,717	258,266
1963	10,227,330	2,946,188	1,417,970	344,823
1964	6,276,077	1,069,009	566,935	99,991
1965	9,383,250	4,070,458	1,913,340	555,112
1966	6,747,110	2,064,690	855,224	185,884
1967	12,038,810	3,287,674	2,803,498	515,572
1968	6,749,580	1,601,556	720,263	120,402
1969	12,613,200	3,491,335	5,079,110	+
1970	10,612,900	3,200,343	1,544,692	357,768
1971	11,469,610	3,161,669	894,910	189,987
1972	6,514,310	847,191	561,738	115,928
1973	9,348,930	2,452,465	1,196,399	372,698
1974	15,421,120	3,911,792	1,396,480	334,998
1975	9,950,479	2,878,060	1,419,050	346,175
1976	5,759,020	619,528	772,387	172,327
1977	2,777,030	219,680	209,982	35,934
1978	8,713,250	3,789,472	2,258,077	503,344
1979	6,524,686	1,606,642	1,318,140	268,617
1980	15,053,100	3,068,774	3,020,670	575,899
1981	+	+	890,070	188,671
Total	208,699,272	57,788,684	34,493,774	6,511,536
Annual Averages	8,695,803	2,407,862	1,379,751	310,073
NOTES:				
cfs-day = The volume of water obtained through the continuous flow past a certain point, measured in cubic feet per second over a period of 24 hours.				
+ = Data unavailable.				
SOURCES:				
USGS 1994b, 1994c.				

Table S-1. Mean Discharge and Suspended Sediment Loads

Estimates from previous studies indicate that about 70 to 80% of the sediment that enters the Delta is ultimately transported into the Bay system. An estimated 15 to 30% of the sediments are deposited in the Delta channels (Corps 1967 and Conomos 1976). The remaining 5 to 7% is transported out of the Delta-Bay system along with water exports (De Groot et al. 1984).

Suspended sediment measurements in the exports have been made by DWR and the U.S. Bureau of Reclamation (Reclamation) (1973-74) (Arthur and Lederquist 1976). Rough calculations of Reclamation's measurements indicate that 200,000 to 300,00 tons of fine sediments were exported from the Delta with the 4 million acre-feet of water exported by the state and federal water projects in water year 1973-74. The sediment transport in the southern Delta channels seems to vary seasonally, with deposition occurring in winter and resuspension of part of this deposited material occurring in summer (RMA 1983).

Dredging of channels in the Delta is another mechanism by which sediment material is removed from the system. U.S. Army Corps of Engineers (Corps) data (Table S-2) indicate a 16-year annual average of 665,968 tons of sediment dredged from the Sacramento River near Rio Vista and 292,163 tons dredged from the Stockton Deep Water Channel. An unknown amount of material is dredged by local agencies and districts for levee stability work. The Corps stockpiles the dredged material in upland spoil areas. Some of this material is reused as landfill or construction materials.

Sediment inflow and outflow to the system are shown in Table S-3. The flow regime and transport of sediment vary seasonally and yearly. Annual averages of sediment transported give only a rough accounting of the system.

Limited model studies conducted during the early 1980s have shown that the Delta Cross Channel near Walnut Grove diverts a significant amount of water and associated sediment into the channels in the northern part of the Delta. Because the sill level of the inlet control structure is at a higher elevation than the bottom of the Sacramento River, there is selective withdrawal of sediment into the Delta Cross Channel. The coarser bed load continues on down the Sacramento River while some of the suspended sediments at and above the sill level are diverted. If the sediment load in the Sacramento River is at carrying capacity, the reduction in flow caused by diversion through the Delta Cross Channel can cause immediate deposition, resuspension, and transport downstream.

Bay Region

SOILS DESCRIPTION

BASIN-LAND/BASIN RIVER SOILS

Basin lands consists of organic-rich saline soils adjacent to the Bay and poorly drained soils somewhat farther from the Bay.

Sacramento Deep Water Channel				Stockton Deep Water Channel		
Year	Cubic Yards	Tons	River Mile	Cubic Yards	Tons	River Mile ^a
Prior to 1966	No Records Prior to 1966					
1966	2,220,000	3,296,700		401,688	596,507	7
1967	183,830	272,988		430,542	639,355	
1968	--			613,467	910,998	28-40
1969	890,554	1,322,473	7-14 35-42	473,961	703,832	37-40
1970	--			--		
1971	712,807	1,058,518	3-14	15,000	22,275	
1972	146,000	216,810	8-15	372,081	552,540	37-40
1973	--			--		
1974	1,065,324	1,582,006	26-33	--		
1975	314,300	466,736	9-15	--		
1976	--			--		
1977	--			--		
1978	270,485	401,670	4-15	841,161	1,249,124	37-41
1979	--			--		
1980	--			--		
1981	1,372,110	2,037,583	33-42	--		
1982	1,083,600	cy as of 12-82				
1983						
Total	7,175,410	10,655,434		3,147,900	4,674,631	
Annual Average	448,463	665,968		196,743	292,163	
NOTES:						
Data given in cubic yards. Conversion to tons by: 1.5 tons/yd ³ .						
Dredge material analysis by Corps determined mean mass of 110 lbs/ft ³ for bottom sediments (110 lbs/ft ³ = 1.5 tons/yd ³).						
^a River mile from confluence of Sacramento and San Joaquin Rivers						
SOURCE: Rompaia pers. comm.						

Table S-2. Annual Dredging from the Delta Conducted by the Corps

	Percentages	Suspended Load	Bedload ^a	Total
Sediment Entering Delta (Annual Averages - Tons)				
From:				
Sacramento River	40	2,407,862	345,250	2,753,112
San Joaquin River	40	310,073	46,500	356,573
Local	20	1,740,000	260,000	2,000,000
Return from Bay	<u>Minimal</u>	<u>--</u>	<u>--</u>	<u>--</u>
Total	100	4,457,935	651,750	5,109,685
Estimated total = 4.5 to 5.2 million tons/year				
Sediment Deposited in Delta				
Estimated 15-30% = 0.7 to 1.6 million tons/year				
Sediment Leaving Delta (Annual Averages - Tons)				
To:				
San Francisco Bay	70-80			3,150,000 to 4,160,000
With exports	5-7	200,000-300,000 ^b		
By dredging:	13-15			
Sacramento River			665,970	
San Joaquin River			292,160	
Estimated total = 4.5 to 5.4 million tons/year				
NOTES:				
^a Bedload is estimated to be 15% of suspended load.				
^b One hydrologic year measurement for 1973 to 1974, not an annual average.				

Table S-3. Sediment Inflows and Outflows

VALLEY LAND SOILS

Valley land soils are generally found on gently sloping alluvial fans that surround the floodplain and basin lands and, along with floodplain alluvial soils, represent the most important agricultural group of soils in California. In the Bay area, most of the floodplain and valley land soils have been urbanized.

TERRACE LAND SOILS

Terrace land soils are found along the southeastern edge of the San Francisco Bay area at elevation 5 to 100 feet above the valley land. Most of these soils are moderately dense soils of neutral reaction.

UPLAND SOILS

Upland soils of the foothills and mountains which surround the Bay are formed in place through the decomposition and disintegration of the underlying parent material. The most prevalent upland soils group is that with a moderate depth to bedrock (20 to 40 inches), with lesser amounts of the deep depth (>40 inches) and shallow depth (<12 inches) to bedrock soil groups being present. Moderate depth soils are generally dark colored, fairly high in organic matter, and constitute some of the best natural grazing lands of the state. Deep soils occur in the high rainfall zones at the higher elevations in the Coast Range. They generally support the forested lands in the Bay Region and are characterized by acid reaction and depths to bedrock of 3 to 6 feet. Shallow soils occur in the medium-to-low rainfall zone. They are loamy in character and are used principally for grazing.

GEOLOGIC CONDITIONS

Geologic forces that formed the Bay are still active today. Geologic formations which commonly form the older bedrock complex are comprised of sedimentary, igneous, and metamorphic rocks of the Franciscan Group. The geologic structure is continually changing as evidenced by crustal movement and the high degree of faulting and shearing of the Franciscan Formation (SWRCB 1975).

Long mountain ridges, characteristic of the Bay region, form part of the Coast Ranges, a series of geologically youthful mountains, ranges, and major valleys. The Golden Gate provides the only break in this north-south barrier between the Pacific Ocean and the Central Valley. The Bay estuary is the largest coastal embayment on the Pacific coast, with an area of 1,240 km². With an average depth of 6 m at mean lower low water, the Bay is characterized by broad shallows incised by narrow channels that are typically 10 to 20 m deep. The deepest channel are at the Golden Gate (110 m) and Carquinez Strait (27 m) (Cloern and Nichols 1985).

Sacramento River Region

SOILS DESCRIPTION

VALLEY LAND SOILS

Valley land soils are generally found on flat to gently sloping surfaces, such as on flood plains and on alluvial fans. These well-drained soils include some of the best all-purpose agricultural soils in the state. Alluvial-deposited soils are present in the Sacramento River Region. Figure 2 in the technical report shows the distribution of all Central Valley alluvial soils.

VALLEY BASIN LAND SOILS

Soils in this topographic division occupy the lowest parts of the Central Valley. The three general groups within this division are organic soils, imperfectly drained soils, and saline/alkali soils. In the Sacramento River Region, imperfectly drained soils exist. Imperfectly drained soils generally contain dark clays and have a high water table, or are subject to watercourse overflows. These soils are found in the troughs of the Sacramento Valley, as shown in Figure 2 in the technical report. When irrigated, these soils are used extensively for rice. They tend to be gray to dark gray, have a high clay content that forms clods, and may be neutral to slightly calcareous.

TERRACE LAND SOILS

Terrace land soils are found along the edges of the Central Valley at elevations from 5 to 100 feet above the valley floor. Several groups of terrace soils surround the floor of the Central Valley. Two of the more widespread groups are the brown neutral soil and the red iron pan soils. Terrace soils are grouped together and shown in Figure 2 in the technical report.

Brown neutral soils consist of moderately dense, brownish soils of neutral reaction. These soils are found in areas receiving 10 to 20 inches of rain per year. On the west side of Sacramento Valley, these terrace soils tend to have a loamy texture. This soil group is commonly used for irrigated pasture; however citrus orchards are grown in some areas.

The red iron pan soils have a red-iron hardpan layer and are found along the east side of the Sacramento Valley. These soils consist of reddish surface layers with dense silica-iron cemented hardpans, which are generally about one foot thick. Some of these hardpan soils have considerable amounts of lime. They occur in areas receiving 7 to 25 inches of rain per year. Dry farming practices produce fair results in hay, grains, and pasture. Following ripping, these soils are well suited for orchard and vineyard development.

UPLAND SOILS

The upper watersheds in the CALFED Study Area mainly drain upland soils. Upland soils are found on the hilly to mountainous topographic areas surrounding the Central Valley and are formed in place through the decomposition and disintegration of the underlying parent material. The more widespread upland soil groups in the Study Area include shallow depth (< 20 inches), moderate depth (20 to 40 inches), and deep depth (> 40 inches) to bedrock components. Shallow depth and deep depth upland soils are more common in the Sacramento River Region due to geographic location and elevation range. (See

Figure 2 in the technical report.) Soils on the west side of the Central Valley have mostly developed on sedimentary rocks while those on the east side typically developed on igneous rocks.

Shallow upland soils are found in the Sierra Nevada and Coast Range foothills that surround the Central Valley. These soils have a loam-to-clay-loam texture with low organic matter content, and some areas have calcareous subsoils. They are usually underlain by weathered bedrock, at a depth of less than two feet. These soils are found in areas of low to moderate rainfall that support grasslands used primarily for grazing. Tilled areas are subject to considerable amounts of erosion. Very shallow upland soils are found on steep slopes, often at high elevations. They consist of stony clay loam or stony loam and are not useful for agriculture or timber because of their very shallow depth (< 12 inches to bedrock), steep slopes, and stony texture. As such, they are also rated very low for grazing purposes.

Deep upland soils are found at the higher elevations in the Sierra Nevada, Klamath Mountains, and Coast Ranges on hilly to steep topography. These soils occur in the high rainfall zones (35 to 80 inches per year) and are characterized by moderate to strongly acidic reaction, especially in the subsoils, which can extend from 3 to 6 feet before reaching bedrock. Bedrock in these areas usually consist of meta-sedimentary or granitic rocks. Soils forming on granitic rocks are composed of decomposed granitic sands. Deep upland soils occur in the high rainfall zones, receiving 35 to 80 inches of precipitation per year, at the higher elevations in the mountains surrounding the valley. Upland soils are important timber lands in the upper watersheds of the Sacramento River Region.

GEOLOGIC CONDITIONS

KLAMATH MOUNTAINS

The Klamath Mountain Province covers about 12,000 square miles of northwestern California between the Coast Ranges on the west and the Cascade Range on the east. The Klamath Mountains consist of a number of individual mountain ranges that trend north-south. They consist of Paleozoic meta-sedimentary and meta-volcanic rocks and Mesozoic igneous rocks. These mountains may be a northwest extension of the Sierra Nevada, although the connection is obscured by the younger alluvial deposits of the Central Valley and the volcanic flows of the Cascade Range and the Modoc Plateau. Thompson Peak located in the Trinity Alps rises to an elevation of 8,936 feet, and is the tallest peak in the Klamath Mountains. Although the peaks of the Klamath Mountains are lower than those of the Sierra Nevada, some of the higher peaks in the Trinity Alps have been subject to extreme glaciation due to their more northerly location.

The Klamath Mountains have a very complex geology. The province is primarily formed by several mountain belts consisting of the eastern Klamath Mountain belt, central metamorphic belt, and the western Paleozoic, Triassic, and Jurassic belts. Between the belts, low-angle thrust faults allow eastern fault blocks to be pushed westward and upward. The Klamath Mountain belt consists of up to 40,000 vertical feet of eastward dipping Ordovician to Jurassic marine deposits. The central metamorphic belt contains Paleozoic hornblende, mica schists, and ultramafic rocks. The western Jurassic, Triassic, and Paleozoic belts consist of slightly metamorphosed sedimentary and volcanic rocks.

COAST RANGES

The Coast Ranges Province extends 600 miles from the Oregon-California border in the north to the Transverse Range in southern California. As the name suggests, the Coast Ranges parallel the California coast along the Pacific Ocean and extend inland from 20 to 80 miles.

The Coast Ranges consist of a parallel series of mountain ranges and structural valleys. The Mendocino Range is one of the longer and higher ranges with some of the peaks exceeding 6,000 feet. The Diablo Range lies west of the San Joaquin Valley and extends from Mt. Diablo southeast to the Kettleman Hills. Mt. Tamalpais marks the northern limit of the Santa Cruz Mountains, which continue southward down the San Francisco Peninsula to Monterey Bay. The San Francisco Bay is a structural depression between the Diablo Range on the east and the Santa Cruz Mountains on the west. The Salinas Valley is the longest continuous valley in the province. It is bounded by the Gabilan Range on the east side and the Santa Lucia Range on the west. The Calaveras and Hayward faults are northwest-trending faults in the central Coast Ranges. The San Andreas fault is a northwest-trending fault in the northern, central, and southern Coast Ranges. The faults of the Coast Ranges are generally northwest-trending, strike-slip faults with predominately right-lateral displacement with some vertical offset.

The Coast Ranges consist of Mesozoic marine sedimentary and meta-sedimentary rocks that have undergone intense folding and faulting. Mesozoic granitic rocks are exposed in the Gabilan Range and the Santa Lucia Range. Some Cenozoic volcanic rocks are exposed in the Napa and Sonoma valleys and in the Diablo Range east of Hollister.

CASCADE RANGE/MODOC PLATEAU

The Cascade Range and Modoc Plateau are described together because of their geologic similarities. In California, the Cascade Range/Modoc Plateau Province borders the Klamath Mountains to the west, the Central Valley to the southwest, and the Sierra Nevada to the south, covering about 13,000 square miles of the northeast corner of California. They are geologically young provinces with a large variety of volcanic rocks. The Cascade Range includes the composite volcanoes, which in California include Mt. Shasta (elevation 14,162 feet) and Mt. Lassen (elevation 10,457 feet). Mt. Lassen erupted intermittently between 1914 and 1917, making it the only California volcano active in this century. Evidence indicates that Mt. Shasta erupted during the eighteenth century. The Cascade Range composite volcanoes extend north to British Columbia.

The Cascade volcanics have been divided into the Western Cascade series and the High Cascade series. The Western Cascade series consists of Miocene-aged basalts, andesites, and dacite flows interlayered with rocks of explosive origin, including rhyolite tuff, volcanic breccia, and agglomerate. This series is exposed at the surface in a belt 15 miles wide and 50 miles long from the Oregon border to the town of Mt. Shasta. After a short period of uplift and erosion that extended into the Pliocene, vulcanism resumed, creating the High Cascade volcanic series. The High Cascade series forms a belt 40 miles wide and 150 miles long, lying just east of the Western Cascade series rocks. Early High Cascade rocks formed from very fluid basalt and andesite flows that extruded from fissures to form low-elevation shield volcanoes. Later eruptions during the Pleistocene had a higher silica content, causing more violent eruptions, and forming the large composite cones of the High Cascades, like Mt. Shasta and Mt. Lassen.

The Modoc Plateau consists of a high plain of irregular volcanic rocks of basaltic origin. The numerous shield volcanoes and extensive faulting of the plateau give the area more relief than normal for a plateau. The Modoc Plateau averages 4,500 feet in elevation and constitutes a small part of the Columbia Plateau, which covers extensive areas of Oregon, Washington, and Idaho.

SIERRA NEVADA

The Sierra Nevada is the tallest, broadest, and most continuous mountain range in California. It extends northwest for more than 400 miles. The foot of the Sierra Nevada extends west below the Central Valley Province, forming a deeply submerged, east-west sloping floor. On the north it is bounded by the Cascade Range and Modoc Plateau. To the south it is separated from the Transverse Range by the

Garlock Fault. East of the Sierra Nevada, the Basin and Range Province extends eastward to Utah. In the southern Sierra Nevada, Mt. Whitney, the tallest mountain in the contiguous United States, rises 14,494 feet (USGS map data) above sea level. In contrast, the floor of Death Valley, the lowest point in the United States lies at an elevation of 282 feet below sea level (USGS map data), approximately 90 miles to the east of the Sierra Nevada crest.

The Sierra Nevada Province is generally composed of a very large Mesozoic Sierran granitic batholith and associated older metamorphic rocks. In some areas of the northern Sierra Nevada, significant areas of Tertiary sediment and volcanic rocks overlie the igneous core. The Sierra Nevada resembles a plateau that is tilted from its highest point in the southeast primarily to the west and secondarily to the north. Thus its western edge is depressed and the eastern edge is thrown high up into the air. The Sierra Nevada batholith rises from beneath the Central Valley an average west-to-east slope of between 3 and 5 degrees, to its highest points along the southeastern peaks, before it drops off abruptly along its eastern fault escarpment. This fault marks the eastern edge of the Sierra Nevada Province and the western limit of the Basin and Range Province.

CENTRAL VALLEY

The Central Valley Province is composed of tertiary sediments and volcanics, and is a northwest-trending asymmetric trough 400 miles long and averaging 50 miles wide. It is bound on the west by the pre-Tertiary and Tertiary semi-consolidated to consolidated marine sedimentary rocks of the Coast Ranges. The faulted and folded sediments of the Coast Ranges extend eastward beneath most of the Central Valley. The east side of the valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada.

Pre-Tertiary marine sediments account for about 25,000 feet of the total consolidated depth of sediments deposited in the sea before the rise of the Coast Ranges. Marine deposits continued to fill the Sacramento Valley until the Miocene Epoch, when the last seas receded from the valley. Then, continental alluvial deposits from the Coast Ranges and the Sierra Nevada began to collect in the newly formed valley. In total, the Sacramento Valley is filled with about 10 and 6 vertical miles of consolidated and unconsolidated sediments, respectively.

The valley floor is divided into several geomorphic land types, including dissected uplands, low alluvial fans and plains, river floodplains and channels, and overflow lands and lake bottoms. The dissected uplands consist of consolidated and unconsolidated continental deposits of Tertiary and Quaternary origins that have been slightly folded and faulted.

The alluvial fans and plains consist of unconsolidated continental deposits that extend from the edges of the valley toward the center of the valley floor. The alluvial plains cover most of the valley floor and make up some of the intensely developed agricultural lands in the Central Valley. Alluvial fans along the Sierra Nevada consist of high percentages of clean, well-sorted gravels and sands. Fans extending from the Coast Ranges streams are less extensive. West-side fans tend to be poorly sorted and contain high percentages of fine sand, silt, and clay. Interfan areas between major alluvial fans of the east side of the valley are drained by smaller intermittent streams similar to those on the west side. Thus, they tend to be poorly sorted and have lower permeabilities than the main fan areas. In general, alluvial sediments of the western and southern parts of the Central Valley tend to have lower permeabilities than do similar deposits on the east side.

River floodplains and channels lie along the major rivers and, to a lesser extent, along the smaller streams that drain into the valley from the surrounding Coast Ranges and Sierra Nevada. Where rivers

are incised into their alluvial fans, some well-defined floodplains have developed. These deposits tend to be coarse and sandy in the channels, and finer and silty in the floodplains.

Several secondary geologic structures are found within the Central Valley. The Red Bluff Arch in the northern end of the Sacramento Valley consists of a series of northeast-trending anticlines and synclines, which act as a groundwater barrier between the Sacramento Valley and the Redding Basin. East of Colusa in the central part of the Sacramento Valley, the Sutter Buttes rise 2,000 feet above the valley floor. The Sutter Buttes are remnants of an ancient, volcanic cone 10 miles in diameter.

San Joaquin River Region

SOILS DESCRIPTION

VALLEY LAND SOILS

The valley lands in the San Joaquin River Region consist of both alluvial and aeolian soils. The alluvial soils consist of calcic brown and noncalcic brown soils and gray desert soils, which are found on the alluvial fan and floodplains that receive low rainfall (4 to 7 inches annually). The gray desert soils appear in the western San Joaquin Valley as light-colored calcareous soil low in organic matter. These soils are too dry to produce crops without irrigation. When irrigated, they are valued for alfalfa, cotton, and flax.

Aeolian-deposited and wind-modified soils of the San Joaquin Valley are noncalcic brown sand soils. These soils primarily are found on the east side of the San Joaquin Valley, as shown in Figure 2 in the technical report. Soils in this area receive 8 to 13 inches of rainfall annually. These soils are light brown, sandy, and neutral to acid. With irrigation, these soils may produce many crops including grapes, sweet potatoes, watermelons, and alfalfa. However, they are prone to wind erosion, have low water-holding capacity, and are somewhat deficient in plant nutrients.

VALLEY BASIN LAND SOILS

Soils in this topographic division occupy the lowest parts of the Central Valley. The three general groups within this division are organic soils, imperfectly drained soils, and saline/alkali soils. In the San Joaquin River Region, imperfectly drained soils and saline/alkali soils exist.

Imperfectly drained soils generally contain dark clays and have a high water table or are subject to watercourse overflows. These soils are found in the troughs of the San Joaquin Valley, as shown in Figure 2. Some San Joaquin Valley soils contain alkali. Dry land farming on these lands produces wheat and barley. Native pasture and irrigated pasture also grow well on this soil.

Saline/alkali soils are characterized by excess salts (saline), excess sodium (sodic), or both (saline-sodic). In many of the older soil surveys, salinity and sodicity were jointly referred to as alkalinity. A distinction was sometimes made since the saline soil frequently formed a white crust on the surface and was called "white alkali," and the soils with excess sodium appeared to be "black," and thus given the term "black alkali". All three are fairly common throughout the San Joaquin Valley as shown on Figure 2 in the technical report. In uncultivated areas, saline soils are used for saltgrass pasture and

native range. Some of these soils support seasonal salt marshes. In areas of intermediate to low rainfall, the soils often have excess sodium as well as salt.

TERRACE LAND SOILS

The soils in the terrace lands of the San Joaquin River Region are similar to those found in the Sacramento River Region. The two widespread soil groups are the brown neutral soils and red iron pan soils. Figure 2 shows the location of these soils. The brown neutral soils tend to have a clayey texture, making it suitable for irrigated pasture; however, citrus orchards are grown in some areas. Following ripping, these soils are suitable for orchard and vineyard development.

UPLAND SOILS

As in the Sacramento River Region, upland soils are found on hilly to mountainous topography and are formed in place through the decomposition and disintegration of the underlying parent material. The upland soils in the San Joaquin River Region include shallow depth, moderate depth, and deep depth to bedrock. Two upland soil groups, shallow depth and deep depth, are discussed in "Soils Description" of "Sacramento River Region." The moderate depth to bedrock soil group is discussed below. Figure 2 in the technical report shows the location of the upland soils.

Moderate depth to bedrock soil is found on hilly to steep upland areas having medium rainfall and that can support grasslands. These soils have a sandy-loam-to-clay-loam texture and a depth to weathered bedrock of about 2 feet. This slightly acidic soil group is dark and is found in Stanislaus County and Merced County foothills east of the valley floor.

GEOLOGIC CONDITIONS

Within the Central Valley, lake bottoms of overflow lands include the historic beds of Tulare Lake, Buena Vista Lake, and Kern Lake, as well as other less-defined areas in the valley trough. Near the valley trough, fluvial deposits of the east and west sides grade into fine-grained deposits. No extensive lakebed deposits are present in the Sacramento Valley; however, the San Joaquin Valley has several thick lakebed deposits. The largest lake deposits in the Central Valley are found beneath the Tulare Lake bed where up to 3,600 feet of lacustrine and marsh deposits form the Tulare Formation. This formation is composed of extensive clay layers, the largest being the Corcoran Clay Member which is widespread in the western and southern portions of the San Joaquin Valley. The Corcoran Clay member is a confining layer that separates the upper, semi-confined to unconfined aquifer from the lower, confined aquifer.

In the San Joaquin Valley, a faulted ridge known as the Stockton Arch extends from the Sierra Nevada to the northern Diablo Range. Along the west side of the San Joaquin Valley, the faulting and folding of the adjacent Coast Ranges are present in the Central Valley in the Kettleman Hills, Elk Hills, Lost Hills, and Buena Vista Hills. The northeast-trending White Wolf Fault is believed to be part of the Bakersfield Arch, which is located in the southern end of the valley.

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CALFED

**TECHNICAL REPORT
ENVIRONMENTAL CONSEQUENCES**

GEOLOGY & SOILS

DRAFT

March 1998



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LIST OF ACRONYMS

CALFED	CALFED Bay-Delta Program
CVP	Central Valley Project
EC	electrical conductivity
SWP	State Water Project
TDS	total dissolved solids

GEOLOGY & SOILS

INTRODUCTION

This technical report discusses impacts on geology and soils associated with implementing the CALFED Bay-Delta Program (Program).

Geologic conditions and soil quality depend on the characteristics of soils (for example, erodibility and organic content) or use of the soil (for example, agricultural and irrigation practices), and the composition and condition of underlying materials and aquifers. Program alternatives could affect soil conditions, subsidence, and seismic hazards through actions that affect the quantity and quality of irrigation water applied to soils, changes to the amount of land under irrigation, improvements to Delta levees, relocation of infrastructure in the Delta, construction of new storage and conveyance facilities, and changes to agricultural practices, groundwater management, and vegetative communities.

ASSESSMENT METHODS

This assessment encompasses analyses of soil changes that could result directly from construction of new facilities or conversion of lands from one use to another, and analyses of indirect effects of changes in policies, resources, or economics. The assessment of the effects of changes on soils and geologic conditions addresses both the direct and indirect consequences of Program actions.

Two types of analyses have been included:

- changes in areal extent due to direct loss, conversion, or creation of soil types and geologic conditions; and
- changes in the quality of soil types and geologic conditions.

This programmatic-level assessment does not provide site-specific details or estimates of acreages potentially affected for a given alternative. Potential increases or decreases in the areas of given soils were qualitatively estimated by region.

The programmatic assessment of geology and soils evaluated potential changes to the following resource categories and assessment variables listed below. Supporting variables that can potentially influence the resource categories follow each category.

- Surface soil erosion
 - Agricultural soil loss due to area cultivated and agricultural practices;
 - Irrigation;
 - Wind erosion; and
 - Stormwater sheet, rill, and gully erosion.
- Channel, basin, shore, and shallows erosion and sedimentation
 - Velocities and flows;
 - Channel and cross sectional configurations;
 - Longitudinal variations, slopes, and energy gradients;
 - Channel roughness (Manning's n);
 - Bank protection and vegetation;
 - Channel islands;
 - Sediment loads; and
 - Salinity gradient, location, and temporal variability.

- Soil salinity
 - Soil geology;
 - Applied water quality (electrical conductivity [EC] or total dissolved solids [TDS]); and
 - Agricultural drainage.
- Soil drainage characteristics
 - Soil percolation rates.
- Subsidence caused by mass loading from overburden and oxidation of organic content
 - Levee mass overburden,
 - Dam and reservoir overburdens,
 - Fill mass overburden (island interiors),
 - Organic soil content (especially peat),
 - Soil moisture, and
 - Ground disturbance and tilling practices.
- Subsidence caused by groundwater withdrawals
 - Groundwater surface elevations,
 - Groundwater withdrawals, and
 - Aquifer clay content.
- Impacts due to change on land surfaces and land use
 - Acres in agricultural use,
 - Acres in open space and habitat use, and
 - Acres in developed use.
- Potential irrigation in Class 6 or unclassified lands (additional acres);
- Impacts on any lands classified as prime and unique farmlands;
- Decreased water quality (increased salinity) for agriculture;
- Unmaintained water levels during the irrigation season;
- Loss of use of agricultural soils for one or more growing seasons;
- Planting orchards or vineyards, adding building structures, or constructing permanent improvements within the rights-of-way of pipelines;
- Agricultural land uses that become susceptible to flooding;
- Alterations to agricultural activities;
- Crop substitution effects on agricultural activities; and
- Direct and cumulative conversions of agricultural soils.
- Open space and habitat use/developed use
 - Potential conversion of wetlands due to agricultural or urban development (additional acres);
 - Irrigation or urban development on lands outside existing place of use;
 - Land acquisition and relocation;
 - Displacement of property owners;
 - Displacement of residences and structures on reservoir islands;
 - Conversion of wetlands and upland habitats for levee construction or modification; and
 - Conversion of recreational facilities to other developed uses.

The following assessment variables determine soil acreages and characteristics:

- Agricultural use
 - Net losses of water deliveries to agricultural contractors resulting in net losses to cropland;
 - Potential irrigation of lands outside existing or proposed place of use (additional acres);

Estimated changes in soil erosion are qualitative because of variability in soil type, soil erodibility, slope, and land management throughout the regions.

Projection of soil salinity impacts are based on estimates of the affected soils and degree to which a region's soils would be affected by salts. In the Delta Region, soil salinity depends on the quality of water withdrawn from Delta channels. For the San Joaquin Valley and other water export areas affected by soil salinity problems due to a high groundwater table, differences in projected soil salinity problem areas were based on differences in the electrical conductivity of export water, the resultant requirements for excess irrigation water to flush salts from the soils, and expected effects on groundwater levels. Plans for agricultural tailwater drains also were considered. In addition, the effects of using groundwater and project water as alternative sources were assessed.

Assessing subsidence resulting from groundwater withdrawals was based on changes in the amounts and reliability of delivered water, and the resulting changes in the rates of groundwater pumping.

The geology and soils impact assessment variables are closely related to other resource assessments and methods, including those for terrestrial, open-water, and wetland habitats; water use, water supply, and operations; and recreation. Additionally, results of the geology and soils assessment support analyses of impacts on storage and conveyance, riverine hydraulics, system integrity, biological resources, visual aesthetics, cultural resources, flood control, surface water conditions, water quality, and air quality.

SIGNIFICANCE CRITERIA

Impacts are considered potentially significant if they lead to the following suggested threshold criteria:

- Removal, filling, grading, or disturbance of soils; especially those that support wetlands and riparian communities, special-status

species habitats or communities, or habitat areas designated as critical by state or federal Endangered Species Acts.

- Substantial degradation of the quantity or quality of native soil types or their environmental and water quality protection characteristics in significant watersheds tributary to the Sacramento or San Joaquin rivers.
- Substantial disruption of soils that support vegetation or forage species of importance to wildlife, recreation, agriculture, parklands, or ecologically or economically important fish species.
- Releases of toxic materials from soils or sediments.
- Alterations to, or drainage from, soils or substrates that create conditions that would increase the potential for outbreaks of wildlife diseases.
- Adverse changes in rates of sedimentation and erosion.
- Adverse changes in soil drainage or salinity.
- Soil subsidence and increases in subsidence rates that produce adverse effects (for example, soil losses, reductions in groundwater basin storage capacity, soil compaction, and levee collapse).
- Changes in soil conditions that cause undesirable seepage to adjacent lands.
- Increased potential for soil erosion by wind, waves, and currents.
- Oxidation of, or drainage from, peat soils when this causes adverse effects.
- Increased potential for erosion and mass failure-induced landslides.
- Increased potential for seismic activity or vulnerability of soil-comprised structures to seismic events.

- Disruption of natural or favorable soil profiles and horizons.
- Increased potential for damage from geologic hazards.
- Impacts on any soils on lands classified as prime and unique farmlands.
- Water level changes that would adversely affect soils used for agriculture.
- Impacts on geology and soils resulting from changes in soil conditions or flows of water to and from wildlife refuges.

ENVIRONMENTAL CONSEQUENCES

Comparison of No Action Alternative to Existing Conditions

Under the No Action Alternative geologic conditions and soils would be very similar to the existing conditions described in the Geology and Soils Affected Environment Technical Report. Central Valley Project (CVP) and State Water Project (SWP) operations would remain similar to existing conditions, with increased demands on the system. Channel geometry in the Delta, Bay, Sacramento River, and San Joaquin River regions would not be altered by other than ongoing geomorphologic, irrigation, drainage, and dredging processes. Negative trends in soil erosion, subsidence, and soil contamination are expected to continue and possibly worsen.

The following sections describe the expected conditions in the Delta, Bay, Sacramento River, and San Joaquin River regions relative to existing conditions.

DELTA REGION

The No Action Alternative could result in continued problems to some geomorphologic and soils resource areas in the Delta Region, including soil salinity, soil surface erosion and subsidence, soil selenium, and seismic susceptibility of levees to failure.

Current soil salinity problems would be expected to continue in the south and west Delta. South Delta salinity problems are tied to relatively low flows and high salt concentrations in the San Joaquin River inflow. Under the No Action Alternative, farmers could continue to be restricted to growing salt-tolerant crops, because salinity conditions would be similar or somewhat worse than existing conditions. Elevated levels of soil salinity could worsen in the south and west Delta due to seepage and the poor quality of applied water caused by ocean salinity intrusion and increasing high TDS concentrations from increasing amounts of land-derived agricultural drainage.

Under the No Action Alternative, island interior soils would continue to undergo peat oxidation, continuing the soils' susceptibility to wind-induced erosion, and contributing to further levee instability. Erosion of submerged levee slopes and channels would continue. Over time, island surface elevations would decrease.

Existing high selenium concentrations could intensify in channels and in applied irrigation water in the south Delta from land-derived San Joaquin Valley agricultural drainage.

Some Delta levees would continue to be susceptible to seismic failure because of sandy sections and lenses with relatively low density and stability. The susceptibility of Delta levees to seismic failure would be further increased by the continued subsidence, and lack structural integrity of some levees due to inadequate construction materials. Seismic failure of the levees would result in a potentially significant impact on the morphology of Delta channels and on soils on the island interiors.

BAY REGION

The No Action Alternative is not expected to result in any significant changes to geomorphologic or soils conditions in the Bay Region relative to existing conditions.

SACRAMENTO RIVER REGION

In the Sacramento River Region, the primary issue of concern is land subsidence. Land subsidence historically has occurred in the southern portion of the valley. Long-term declines in groundwater levels in this region could result in additional subsidence occurring at rates similar to historical conditions. Surface soil erosion can also be expected to worsen under the No Action Alternative.

SAN JOAQUIN RIVER REGION

Issues in the San Joaquin River Region include subsidence, soil salinity, soil selenium, and surface soil erosion. Land subsidence historically has occurred on the west side of the valley, as well as in the southwestern portion of Tulare County and the southern end of Kern County. Long-term declines in groundwater levels in this region could result in additional subsidence.

With respect to soil salinity and selenium, conditions could worsen as additional salt load is imported to the valley and leached from soils by irrigation and natural discharge from contaminated soils on the west side of the San Joaquin Valley. Agricultural soils could be removed from production in the seriously affected areas. Surface soil erosion can be expected to worsen under the No Action Alternative.

SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

No significant changes to geology and soils are expected to occur in the SWP and CVP Service Areas Outside the Central Valley under the No Action Alternative.

Comparison of CALFED Alternatives to No Action Alternative

Impacts on geology and soils under the Ecosystem Restoration, Water Quality, Levee System Integrity, Water Use Efficiency, Water Transfers and Coordinated Watershed Management Programs would be similar under all alternatives. Actions and impacts under Storage and Conveyance would differ for each alternative.

DELTA REGION

ALL ALTERNATIVES

Ecosystem Restoration Program

The Ecosystem Restoration Program would potentially affect agricultural landforms and soils in the Delta Region. Various sites could be improved throughout the Bay-Delta system by habitat restoration. In addition, the program would include developing floodways and meander zones, and installing fish screens.

Beneficial impacts would include:

- Reduced soil depletion and wind erosion on Delta islands due to habitat restoration. Conversion of agricultural soils for habitat restoration could improve geomorphologic and soil conditions, since habitat restoration would return humus and nutrients to the soils, and protect them from depletion and erosion.

- Reduced levee soil erosion rates due to implementation of modified levee and berm management practices. Agreements with willing levee reclamation districts would promote establishment and maturation of shoreline riparian vegetation. Riparian vegetation could reduce water velocities adjacent to the levees, and thereby reduce soil erosion potential.
- Reduced wave-induced levee soil erosion due to creation of in-channel islands. Protection and maintenance of in-channel islands would reduce wind-fetch, thereby reducing wave generated erosion on nearby levees.

Water Quality Program

The Water Quality Program would reduce water quality degradation from agricultural drainage, urban and industrial runoff, acid mine drainage, wastewater, industrial discharges, and natural sources. Actions would provide beneficial impacts to geology and soils in the Delta Region.

The release of pollutants would be reduced, resulting in a reduction in potential sediment contamination, including salinity and selenium. The Water Quality Program focuses on source control and reducing the release of pollutants into the Bay-Delta system and its tributaries. Activities proposed for the Water Quality Program would remove potential sources of soil and sediment contamination, including salts.

Levee System Integrity Program

Within the Delta Region, Levee System Integrity Program improvements would be implemented primarily on lands used for agriculture; hence changes in soils and geomorphologic conditions would be confined to those lands.

Beneficial impacts would include:

- Reduced subsidence through shallow flooding of central and west Delta lands. The program would reduce subsidence rates

through the creation of wetlands from shallow flooding on about 14,000 acres of land in the Delta.

- Reduced risk of increased salinity on Delta islands. Incorporation of seismic retrofits could reduce the risk of catastrophic levee failures, thereby reducing the risk of salinity intrusion from the ocean, which could increase salinity in the soils.
- Replacement of soils. Beneficial reuse of dredged material could replace soils that have been lost or prevent subsequent losses.

Conversion of agricultural soils for levee construction could result in a potentially significant adverse impact. Conversion of agricultural soils for levee system construction would produce significant changes to geology and soils in the affected areas. Agricultural soils would be covered where new setback levees were constructed. Channel-side soils could be improved by habitat restoration and sediment deposition measures; however, the soils would also be subject to erosion during floods. The beneficial use of dredged material could replace soils that have been lost and/or prevent subsequent losses.

Water Use Efficiency Program

The Water Use Efficiency Program addresses the efficient use of developed water supplies and is principally concerned with policy issues to be implemented by local agencies.

The program would reduce sediment loads from agricultural lands due to on-farm efficiency improvements. On-farm improvements, such as tailwater recovery ponds or installation of pressurized systems (over gravity), could greatly reduce sediment transport from fields to streams and drains. Tailwater ponds would accommodate sediment settlement and containment on or adjacent to agricultural lands. Periodic removal of accumulated sediments from the ponds and placement back onto the fields would be necessary. Pressurized systems typically do not generate surface runoff at rates that cause erosion; therefore, when properly

designed and operated, they do not create sediment transport problems. Sediment transport is not a significant issue in all areas but does pose a problem in sandy or organic soils, such as those in the Delta and areas of the San Joaquin Valley.

Efficiency improvements in irrigation should consider leaching requirements needed to maintain a satisfactory soil environment. Since leaching currently is practiced in most areas, efficiency improvements should not create any potentially significant adverse or beneficial impacts on long-term soil salinity levels.

Subsidence could increase due to localized increased reliance on groundwater. On-farm efficiency improvements could lead to increased reliance on groundwater for two reasons. First, highly efficient irrigation requires more frequent water deliveries, some of which may not be met from surface water sources. Second, less tailwater would be available to secondary users, and these users would need to turn to alternative supplies, such as groundwater. This increased reliance on groundwater could cause localized subsidence, a potentially significant adverse impact.

Water Transfers

The Water Transfer Program would affect geology and soils primarily through changes in land subsidence, erosion, and soil salinity. In addition to the source of water for a transfer, the timing, magnitude, and pathway of each transfer have a tremendous effect on the potential for significant impacts.

Potentially significant beneficial impacts are primarily associated with the transferred water's origin, and include: (1) decreasing erosion and sedimentation through reduced land disturbance from fallowing; and (2) decreasing soil salinity, relative to initial conditions, through replacement of irrigation water from surface water sources with higher-quality groundwater.

Potentially significant adverse impacts are primarily associated with the transferred water's destination, and include: (1) increasing erosion

and sedimentation through reduced soil cover from fallowing; (2) increasing soil salinity by replacing irrigation water with lower quality water from groundwater substitution; and (3) increasing soil salinity by irrigating with a volume of water insufficient to flush the salinity from the soil.

Storage and Conveyance Alternatives

Alternative 1

Configurations 1A and 1B

Conveyance and storage facility improvements are not included in Configuration 1A, and therefore cause no significant adverse impacts to geology and soils. Conveyance improvements for Configuration 1B would be comprised of south Delta modifications and SWP and CVP improvements. Conversion of agricultural soils for Configuration 1B conveyance improvements would have a significant and unavoidable impact if soils that comprise prime farmlands and farmlands of statewide significance are lost. Construction activities required for conveyance improvements could cause disturbance of soils in the vicinity of the project, resulting in a short-term increased potential for erosion. Most construction would take place during the dry season, reducing precipitation-induced erosion. During the wet season, however, erosion rates may increase if disturbed soils have not stabilized sufficiently in time to accommodate the runoff. Short-term increases in erosion rates due to construction of conveyance improvements is considered a potentially significant and mitigable impact.

Increased pumping of water out of the Delta could result in increased flows during some months. The magnitude of change in flow velocities would likely be negligible relative to existing flows, however, and so would not adversely impact soil erosion or sediment transport processes. Therefore, the potential for increased erosion of channel and levee soils would not be less than significant.

Configuration 1C

Reductions in applied salt loads due to increased releases and downstream flows from additional storage facilities during low-flow periods would benefit soils in the Delta Region by lowering salt concentrations in applied water. This impact also applies to Configurations 2B, 2E, 3B, 3E, 3H, and 3I. New groundwater and surface water storage would increase the amount of water available during summer and fall to dilute salinity in waters from tributaries with return flows with potentially high concentrations of salts. The additional flows in summer and fall also would reduce salinity intrusion from the ocean and transport more dissolved salts to the ocean, thereby reducing applied salt loads.

Conveyance improvements would be similar to those for Configuration 1B but would expand the range of south-Delta modifications and SWP and CVP facilities. In addition to impacts described under Configuration 1B and below, levee soil and channel erosion rates would be reduced from south-Delta modifications. Enlargement of channels in the south Delta would reduce water velocities in those channels, reducing the potential for levee soil and Channel substrate erosion. In the north Delta channel levee erosion may occur because channels are not being enlarged under Configuration 1C in that area.

Alternative 2

Configurations 2A, 2B, and 2E

Geologic features and soils potentially affected by conveyance improvements would be primarily agricultural, with some urban modifications at Hood. Potential impacts of south-Delta modifications would affect agricultural soils. Potential impacts of conveyance improvements to the SWP and CVP facilities in the south Delta primarily would affect agricultural channel-side geology and soils. The impacts described under Configurations 1B and 2A related to the conversion of agricultural land for conveyance improvements and associated construction

activities also apply to Configurations 3E, 3H, and 3I.

Construction of setback levees and widened channels would reduce the potential for levee soil erosion. Creation of widened channels would increase their cross-sections, thereby reducing velocities. Vegetation could protect exposed portions of levees from potential erosion.

New groundwater and surface water storage under Configurations 2B and 2E would provide beneficial impacts by increasing the amount of fresh water available during the summer and fall months. This increase in freshwater would dilute salinity in waters from tributaries with return flows that have potentially high concentrations of salts. The additional flows in the summer and fall would also reduce salinity intrusion from the ocean and transport more dissolved salts to the ocean, thereby reducing applied salt loads. This beneficial impact also applies to Configurations 3B, 3E, 3H, and 3I.

Alternative 3

Configuration 3A

Configuration 3A includes potentially significant adverse impacts to agricultural landforms and soils in the Delta Region and some developed areas along the Interstate 5 corridor due to the conversion of land for conveyance improvements and associated construction activities. These impacts, described under Configurations 1B and 2A, also apply to Configurations 3E, 3H and 3I.

Configurations 3B, 3E, 3H, and 3I

Potentially significant adverse impacts under Configurations 3B, 3E, and 3I include the loss and conversion of agricultural soils to new in-Delta water storage facilities and increased potential for catastrophic levee failure due to earthquake-induced liquefaction.

In-Delta storage may be developed by flooding one or more Delta island interiors with surplus water during times of high flows. Stored water

may be later used to provide continuing water supplies for agricultural and environmental purposes during environmentally critical periods. A significant adverse impact of such in-Delta water storage facilities would be the loss of prime Delta farmland due to inundation at the storage site.

Structures and levees at the site may also be susceptible to seismic disturbance by earthquakes, depending on their proximity to nearby faults and degree of relative ground motion during an earthquake. Sandy levee sections common to many of the Delta island levees, make them susceptible to catastrophic failure resulting from earthquake-induced liquefaction. The potential seismic impacts may be mitigated by upgrading the levees and designing all related structures to meet potential seismic accelerations based on strong-motion studies which use maximum-likelihood earthquakes of nearby faults in the area to refine design parameters.

Impacts on soil erosion from the construction of in-Delta water storage sites would be similar to that described under Configurations 1B and 2A. Impacts of this alternative associated with conversion of agricultural soils are described under Configuration 1B.

BAY REGION

ALL ALTERNATIVES

All alternatives could alter existing in-Delta landforms and soils in the immediate vicinity of the proposed activity or facility; however, no significant effects on geology and soils in the Bay Region are expected. Implementation of Program alternatives also could affect the availability of water resources in the Bay Area; however, potential geologic and soils impacts associated with foreseeable changes in water availability are expected to be minimal and less than significant. The only potential affect would be associated with changes in sediment transport out of the Delta and into the Bay. CALFED alternatives likely would cause only

minor decreases in sediment transport from the Delta to the Bay.

Ecosystem Restoration and Water Quality Programs

Direct, indirect, and construction-related activities associated with the Ecosystem Restoration and Water Quality programs could alter or displace soils in the immediate vicinity of activities, but are not expected to have a significant adverse effect on geology and soils in the Bay Region.

As in the Delta region, reductions in point-source and non-point source pollutants will provide beneficial impacts to the geology and soils resources of the Bay Region by decreasing toxic metals and organic compounds that accumulate in bottom sediments in the Bay.

Coordinated Watershed Management

Potential beneficial effects of the coordinated watershed management activities include overall lowering of sediment input to watershed streams and localized lowering of the potential for seismically induced landslides.

SACRAMENTO RIVER REGION

ALL ALTERNATIVES

Direct and construction-related impacts of the Ecosystem Restoration, Water Quality, Levee System Integrity, and Water Use Efficiency programs, and Storage and Conveyance could alter or displace soils in the immediate vicinity of activities, but are not expected to significantly affect geology and soils in the Sacramento River Region as a whole.

Ecosystem Restoration Program

Certain targets of the Ecosystem Restoration Program could beneficially affect Sacramento River geomorphologic processes, including:

- Establishment of stream meander belts,
- Gravel recruitment, and
- Reduced use of seasonal diversion dams.

Actions to establish stream meander belts include purchasing riparian lands from willing sellers and restoring floodplains through construction of setback levees. Establishing meander belts would widen the area available for natural channel migration to accommodate the processes of channel erosion and deposition, and allow the stream system to respond more naturally to morphologic changes without the presently imposed physical constraints.

Gravel recruitment actions would include stockpiling gravel at strategic locations for capture by high-stream flows to mimic the natural processes of the streams. This program would be monitored to determine the effects on channel erosion and meander processes.

Removing or reducing seasonal diversion structures would reduce sediment trapping occurring on the affected tributaries, allowing more natural transport of sediment downstream. Depending on the tributary affected, these actions could increase the sediment supply downstream, resulting in sedimentation in the Sacramento River and Delta, and possibly increased dredging in some areas.

Water Quality Program

Reductions in point-source and non-point source pollutants will provide beneficial impacts to the Sacramento River Region by decreasing loadings of toxic metals and organic compounds and by reducing the concentrations of selenium and salts in these and other minor tributaries.

Coordinated Watershed Management

Water quality in the Sacramento River would benefit from watershed management activities that reduce hillslope and stream bank erosion which cause sediment loading and increased turbidity in watershed tributaries. Channel modifications designed to improve conveyance, decrease flow velocities or improve fisheries

habitat may also be implemented. Bank and slope stabilization methods that use native vegetation to protect ground surfaces from wind- and water-induced erosion also increase the potential for developing habitat diversity at the site. Road improvements and road deconstruction efforts could provide beneficial impacts by decreasing road-related erosion and reducing the potential for landslides on over-steepened slopes.

Adverse effects associated with upper watershed management activities can include short-term soil erosion and increased sediment deposition during the construction of stream and watershed restoration projects or roadway improvements. Compaction of soil by heavy equipment during construction will temporarily affect the physical characteristics of the soil; however, long-term post-construction effects are expected to be beneficial, and include reducing sediment erosion and excess sedimentation in streams due to poorly managed timber-harvesting, livestock grazing, and other land-use activities. Most watershed restoration efforts would include a re-vegetation component to reduce erosion, stabilize hazardous slopes, and provide terrestrial or aquatic habitat.

Water Use Efficiency Program

The Water Use Efficiency Program would generally have the same beneficial and adverse impacts as identified for the Delta Region. Potential reduction of erosion from agricultural fields through use of on-farm efficiency measures is most pronounced in the Sacramento Valley. This would benefit instream water quality by reducing sediment transport to streams and drains.

Soil salinity of agricultural lands in the San Joaquin Valley can potentially be reduced if less (high salinity) water is applied to fields. In turn, this can improve the productive capacity of some fields currently high in soil salinity.

Conjunctive use practices involve using groundwater in combination with surface water for augmenting water supplies. When surplus Sacramento River and/or San Joaquin River

water is available, it would be stored in groundwater basins (aquifers) for times when surface water availability is low. Conjunctive use of groundwater could have a beneficial impact in some areas of the San Joaquin Valley by reducing land subsidence that results from overdraft of groundwater reserves.

Water Transfers

Water Transfers would generally have the same beneficial and adverse impacts as identified for the Delta Region. Land subsidence could be impacted either beneficially or adversely following withdrawals for direct groundwater or groundwater substitution transfers depending on groundwater levels and the net change in storage (input) and withdrawals (output).

Storage and Conveyance Alternatives

Configuration 1A

Reoperation of SWP and CVP facilities could result in increased flows during some months. These increased flows would have greater capacities to transport sediment and erode channel banks than prevail under existing conditions. While sediment transport and erosion is greatest during periods of high flows (for example, during winter and spring), increased flows during lower flow periods also could alter existing erosion and deposition processes. The magnitude of the change would not be likely to adversely impact soil erosion and sediment transport. Some changes could occur, however, and therefore are identified.

Configurations 1C, 2B, 2E, 3B, 3H, and 3I

Agricultural soils would be converted for water storage in the Sacramento River Region. Conversion of agricultural soils for storage facilities is considered a potentially significant and unavoidable impact.

Construction of storage facilities would cause significant adverse impacts due to local ground

disturbances and inundation, the extent of which would depend upon the type and size of storage facilities enlarged or constructed, construction methods and site(s) selected. Reservoir construction would also require construction of access roads and dams. Increased erosion could occur on areas cleared for storage facilities or access roads. Compaction of soil by heavy equipment during construction would temporarily affect the physical characteristics of the soil, including decreasing permeability and increasing runoff.

Any storage facilities sited on streams would have a significant adverse impact by trapping sediments, thereby reducing sediment transport and potentially increasing stream erosion capabilities and altering geomorphologic characteristics downstream of the storage facility. Reductions of stream bedload would be greatest during high flow events. Off-stream storage sites would not directly impact in-stream sediment transport, but may diminish flows in local stream channels due to their placement across minor drainages. Wind- and wave-generated erosion along the shoreline of the reservoir can cause a significant impact by increasing bank erosion and sedimentation at the site. The potential for landsliding in areas around the reservoir may be increased by saturation of adjacent geologic strata as the reservoir is filled.

Conveyance improvements would be located in the Delta Region, and would not significantly affect geology and soils in the Sacramento River Region.

SAN JOAQUIN RIVER REGION

The impacts of Program alternatives on the San Joaquin River Region with regard to surface and levee soil erosion, channel erosion and sedimentation, soil salinity and soil selenium, and seismicity would be similar to the impacts in the Sacramento River Region. In addition, the following beneficial impact could result from the Water Use Efficiency Program.

Subsidence levels could be reduced from increased supplies due to conjunctive use practices. Conjunctive use involves the use of groundwater in combination with surface water. When surplus water was available, it would be stored in aquifers for use when surface water availability was low. Conjunctive use of groundwater basins could reduce overdraft in some areas of the San Joaquin Valley, thereby reducing land subsidence.

SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

None of the proposed alternatives are expected to affect existing landforms or soils in the SWP and CVP Service Areas Outside the Central Valley. Implementation of the alternatives could affect the availability of water resources throughout the service areas; however, secondary potential geomorphologic and soils impacts associated with foreseeable changes in water availability are expected to be minimal and less than significant.

Comparison of CALFED Alternatives to Existing Conditions

The degree to which surface and levee soil erosion, channel erosion and sedimentation, soil salinity and soil selenium, subsidence, and seismicity impact geology and soils resources is dependent on time. Therefore, the same potential impacts described compared to the No Action Alternative would essentially occur when compared to existing conditions, because the same problems with respect to geologic and soils resources that currently exist would continue, though to a greater degree under the No Action Alternative.

Tables 1, 2, and 3 summarize the impacts of the No Action Alternative with respect to existing conditions and the proposed alternatives compared to existing and No Action Alternative conditions. Impacts are summarized for the

Delta, Sacramento River, and San Joaquin River regions respectively. (These tables are at the end of this report.) The Bay Region and CVP and SWP Service Areas Outside the Central Valley are not included because proposed alternatives are not expected to significantly affect these regions.

Comparison of program alternatives to existing conditions indicates that:

- All significant adverse impacts identified when comparing to the No Action Alternative are still significant when comparing to existing conditions.
- CALFED is proposing actions for levee protection, and ecosystem restoration, which could result in additional large-scale land conversions impacting agricultural soils particularly in the Delta. Adverse impacts resulting from the CALFED alternatives combined with the expected future conversion of agricultural lands could result in greater impacts to agricultural soils when compared to existing conditions.
- CALFED is proposing actions under its each of its Program elements that could improve soil quality, vulnerability to seismic failure, and sediment load of streams above the existing condition baseline. All benefits which have been identified when compared to the No Action Alternative are still beneficial when compared to existing conditions.

MITIGATION STRATEGIES

Mitigations are proposed as strategies in this programmatic document and are conceptual in nature. Final mitigations would need to be approved by responsible agencies as specific projects are approved by subsequent environmental review.

The following mitigation measures could be implemented to reduce significant impacts to geology and soils resources:

- Monitor groundwater levels and subsidence in areas of increased reliance on groundwater resources; regulate withdrawal rates at levels below those which cause subsidence;
- Upgrade all levees to Public Law-99 standards;
- Protect flooded Delta island inboard levee slopes against wind and wave erosion with vegetation, soil matting, or rock;
- Implement erosion control measures and bank stabilization projects where needed; this can include grading the site to avoid acceleration and concentration of overland flows, using silt fences or hay bales to trap sediment, and revegetating areas with native riparian plants and wet meadow grasses;
- Protect exposed soils with mulches, geotextiles, and vegetative ground covers to the extent possible during and after project construction activities to minimize soil loss;
- Increase sediment deposition and provide substrate for new habitat by planting terrestrial and aquatic vegetation;
- Measure channel morphology over time to monitor changes due to re-operation of SWP-CVP flows, and implement erosion control measures where needed;
- Re-use dredged materials to reduce or replace soil loss;
- Leave crop stubble from previous growing season in place while fallowing, and employ cultivation methods that will cause the least amount of disturbance to minimize erosion of surface soils;
- Limit the salinity of replacement water, relative to local conditions, in water transfers;
- Ensure that the volume of irrigation water used is always sufficient to flush accumulated salts from the root zone;
- Minimize or avoid direct groundwater transfers or groundwater substitution transfers from regions experiencing long-term overdraft, where subsidence has historically occurred, or where local extensometers indicate that subsidence rates are increasing;
- Utilize Water Transfers in strict adherence to existing laws that regulate groundwater such as Central Valley Project Improvement Act (CVPIA), Water Code Section 1220 prohibiting groundwater from being exported from the Sacramento or Delta-Central Sierra basins unless certain requirements are met, case law that generally only allow groundwater that is surplus to overlying landowners' needs to be appropriated and exported, and Water Code Section 1745.10 that addresses the conditions of "replacement pumping"; and
- Promote geographically broad-based water transfers and ensure that no one area is involved in a disproportionately large amount of transfer activity.

POTENTIALLY SIGNIFICANT UNAVOIDABLE IMPACTS

Significant unavoidable impacts of the Program alternatives may include the loss of agricultural soils, prime farmland and farmland of statewide importance in areas converted for channel widening, levee setbacks, meander belts, and storage or conveyance facilities.

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Surface soil erosion	<p>Widespread wind-induced erosion and loss of Delta soils occur.</p> <p>Levee and surface soil erosion at sites of levee breaks is a serious problem.</p>	<p>Same as existing with the following impact potential modifications:</p> <p>Wind-induced erosion and loss of Delta soils would continue; over time, island surface elevations would decrease as a result.</p>	<p>Same as existing with the following additional impact potential modifications:</p> <p>All - Conversion of agricultural lands to wetlands would reduce wind erosion to extent that alternative acreage is converted; soil losses would be reversed in those areas.</p> <p>All - In-channel islands would reduce wind fetch and lessen consequent wave-induced levee soil erosion.</p> <p>All - Beneficial reuse of dredged material could reduce or replace soils otherwise lost.</p> <p>1B - Increased channel velocities could increase potential for levee soil erosion.</p> <p>1C - Channel enlargements in south Delta would reduce channel velocities and reduce potential for levee soil erosion.</p>	<p>Same as Alternative 1 with the following additional impact potential modifications:</p> <p>All - Levee setbacks and island flooding would reduce potential for both levee and interior island soil erosion and losses.</p> <p>All - Widened channels and additional Clifton Court Forebay intake would reduce channel velocities and lessen levee soil erosion.</p>	<p>Same as Alternative 1 with the following additional impact potential modifications:</p> <p>All - Use of an isolated facility would reduce in-Delta channel velocities and reduce potential for levee soil erosion. The larger the isolated facility, the greater the potential reduction.</p> <p>3E - Would have the greatest potential to reduce wind-induced soil erosion due to inundation, but the highest potential for interior island wave-induced levee soil erosion.</p>

Table 1. Summary of Geology and Soils Impacts in the Delta Region (Page 1 of 5)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Channel erosion and sedimentation	Submerged levee slopes and sub-surface soil erosion at sites of levee breaks are serious problems.	Submerged levee slopes and subsurface soil erosion in channels and at sites of levee breaks would cause serious and worsening problems.	<p>Same as existing with the following additional impact potential modifications:</p> <p>1B - Increased channel velocities could increase potential for channel bank and bottom erosion and subsequent downstream deposition. Additional scour and sedimentation could occur near export pumps.</p> <p>1C - Channel enlargements in south Delta would reduce channel velocities and reduce potential for channel bank and bottom erosion, and subsequent downstream deposition. Additional scour and sedimentation could occur near export pumps.</p>	Same as Alternative 1 with the following additional impact potential modifications: All - Increased channel velocities could increase potential for channel bank and bottom erosion, and subsequent downstream deposition. Additional scour and sedimentation could occur near export pumps.	Same as Alternative 1 with the following additional impact potential modifications: All - Decreased channel velocities could decrease potential for channel bank and bottom erosion, and subsequent downstream deposition. Decreased scour and sedimentation is likely near export pumps; however, it could increase near in-Delta pumps due to decreased channel flow volumes.

Table 1. Summary of Geology and Soils Impacts in the Delta Region (Page 2 of 5)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Soil salinity	Elevated levels of soil salinity occur in south and west Delta due to poor quality of channel seepage and of applied water caused by ocean salinity intrusion and high TDS concentrations from land-derived agricultural drainage.	Elevated levels of soil salinity could worsen in south and west Delta due to seepage and poor quality of applied water caused by increasing amounts of ocean salinity intrusion and high TDS concentrations from increasing amounts of land-derived agricultural drainage.	<p>All - Source control in San Joaquin Valley could reduce salt loads slightly in south Delta. Improved system integrity would reduce risk of catastrophic levee failures, which could cause increased ocean salinity intrusion. Both impacts would tend to reduce risks of increased soil salinity.</p> <p>1B/C - South Delta water quality improvement facilities should reduce salt loads in applied irrigation water there.</p> <p>1C - Additional surface water and groundwater storage would increase amount of water available during summer and fall to dilute land-derived salinity and repulse sea water, thus reducing applied salt loads.</p>	<p>All - Source control in San Joaquin Valley could reduce salt loads slightly in south Delta. Improved system integrity would reduce the risk of catastrophic levee failures which could cause increased ocean salinity intrusion. Both impacts would tend to reduce risks of increased soil salinity.</p> <p>2A/B/D - South Delta water quality improvement facilities (and to some extent three south Delta intake structures) should reduce the salt loads in applied irrigation water there.</p> <p>2B/E - Additional surface water and groundwater storage would increase the amount of water available during summer and fall to dilute land-derived salinity and repulse sea water, thus reducing applied salt loads.</p>	<p>All - Source control in San Joaquin Valley could reduce salt loads slightly in south Delta. Improved system integrity would reduce risk of catastrophic levee failures, which could cause increased ocean salinity intrusion. Both impact would tend to reduce risks of increased soil salinity.</p> <p>3A/B/G - South Delta water quality improvement facilities should reduce the salt loads in applied irrigation water there.</p> <p>3B/E/H/I - Additional surface water and groundwater storage would increase the amount of water available during summer and fall to dilute land-derived salinity and repulse sea water, thus reducing applied salt loads.</p>

Table 1. Summary of Geology and Soils Impacts in the Delta Region (Page 3 of 5)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Soil selenium	High selenium concentrations can be anticipated to recur in the channels and applied irrigation water in south Delta from land-derived San Joaquin Valley agricultural drainage.	High selenium concentrations could intensify in channels and applied irrigation water in south Delta from land-derived San Joaquin Valley agricultural drainage.	All - Essentially the same as No Action except that removal of some lands from production would tend to reduce selenium in agricultural drainage, with amount of reduction depending on geographic area selected for retirement.	<p>All - Source control in San Joaquin Valley could reduce selenium loads slightly in south Delta. This impact would tend to reduce risks of increased soil selenium concentrations.</p> <p>2A-D - South Delta water quality improvement facilities (and to some extent three south Delta intake structures) should reduce salt loads in applied irrigation water there.</p> <p>3B/E - Additional surface and groundwater storage would increase amount of water available during summer and fall to dilute land-derived salinity and repulse sea water, thus reducing applied salt loads.</p>	<p>All - Source control in San Joaquin Valley could reduce selenium loads slightly in south Delta. This impact would tend to reduce risks of increased soil selenium concentrations.</p> <p>3A/B - South Delta water quality improvement facilities should reduce selenium loads in applied irrigation water there.</p> <p>3B/E/H/I - Additional surface and groundwater storage would increase amount of water available during summer and fall to dilute land-derived salinity and repulse sea water, thus reducing applied salt loads.</p>

Table 1. Summary of Geology and Soils Impacts in the Delta Region (Page 4 of 5)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Subsidence caused by peat oxidation	This process occurs in Delta island interiors, where peat is a significant soil constituent. Rate of subsidence is proportional to rate of oxidation, which in turn depends on amount of oxygen available.	Subsidence caused by peat oxidation would continue unabated under No Action Alternative, further intensifying adverse conditions.	All - Habitat restoration activities could reduce subsidence rates since they would restore humus and nutrients to island soils.	All - Same as Alternative 1	All - Same as Alternative 1
Subsidence caused by groundwater withdrawals	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Seismicity	High risk of soil erosion and loss due to moderate to severe earthquake potential. Potential incidents range from single, isolated failure to widespread, catastrophic levee failures.	The existing risk would be further increased and compounded by continued subsidence under No Action Alternative.	Same as existing since upgrading of levees to PL-99 standards would tend to offset effects of continued subsidence.	2A/B/D - Channel improvements and levee setbacks would further reduce the risks. 2E - Further reduced risk due to additional wetland habitat restoration and levee setbacks.	All - The Isolated Facility could relieve some of hydrostatic pressure on Delta levees and resultant potential for soil erosion associated with seismic levee breaks.
Mitigation strategies	Not applicable	Not applicable	All - Upgrading levees to PL-99 standards would mitigate to a degree.	All - Interiors of flooded islands would require protection against erosion with vegetation, soil matting, or rock.	All - Interiors of flooded islands would require protection against erosion with vegetation, soil matting, or rock. 3E - Interiors of flooded islands would require the most protection against erosion with vegetation, soil matting, or rock.
<p>NOTE:</p> <p>All = applicable to all Configurations.</p>					

Table 1. Summary of Geology and Soils Impacts in the Delta Region (Page 5 of 5)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Surface soil erosion	Surface soil erosion is a significant problem in Sacramento River Region watersheds, along levees, and in degraded riparian zones.	Surface soil erosion can be expected to worsen in Sacramento River Region watersheds, along levees, and in degraded riparian zones under No Action.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 1C - Short-term increases would occur during construction of storage facilities.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 2B/E - Short-term increases during construction of storage facilities.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 3B/E/H/I - Short-term increases during construction of storage facilities.
Channel erosion and sedimentation	Surface soil erosion is a significant problem along river banks and in channels of the Sacramento River system and its tributaries.	Surface soil erosion could continue or worsen along river banks and in channels of the Sacramento River system and its tributaries.	All - Reestablishment of stream meander belt on some reaches could help restore natural sediment transport and depositional processes, if properly designed. All - Increased potential for sediment transport and deposition associated with reoperation of SWP and CVP facilities.	Same as Alternative 1. All - Increased potential for sediment transport and deposition associated with new SWP and CVP facilities.	Same as Alternative 2.
Soil salinity	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Soil selenium	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Subsidence caused by peat oxidation	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Subsidence caused by groundwater withdrawals	Localized and currently stabilized	Additional subsidence could occur at historical rates	No change	No change	No change

Table 2. Summary of Geology and Soils Impacts in the Sacramento River Region (Page 1 of 2)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Seismicity	Risk of activity	No change	No change	No change	No change
Mitigation strategies			Careful design of river channel and bank modifications, consistent with fluvial geomorphologic principles. Use of watershed and bank protection measures to reduce erosion. Minimize disruption of natural hydrologic regimes.	Same as Alternative 1.	Same as Alternative 2.
<p>NOTE:</p> <p>All = applicable to all Configurations.</p>					

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Table 2. Summary of Geology and Soils Impacts in the Sacramento River Region (Page 2 of 2)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Surface soil erosion	Surface soil erosion is a significant problem in San Joaquin River Region watersheds, along levees, and in the extensively degraded riparian zones.	Surface soil erosion can be expected to worsen in San Joaquin River Region watersheds, along levees, and in the degraded riparian zones under No Action.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 1C - Short-term increases during construction of storage facilities.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 2B/E - Short-term increases during construction of storage facilities.	All - Watershed management measures included in the Water Quality Program would reduce surface soil erosion potential somewhat. 3B/E/H/I - Short-term increases during construction of storage facilities.
Channel erosion and sedimentation	Surface soil erosion is a significant problem along river banks and in channels of the San Joaquin River system and its tributaries.	Surface soil erosion can be expected to continue or worsen as a significant problem along river banks and in channels of the San Joaquin River system and its tributaries.	All - Reestablishment of stream meander belt on some reaches could help restore natural sediment and transport depositional processes, if properly designed. All - Increased potential for sediment transport and deposition associated with reoperation of SWP and CVP facilities.	Same as Alternative 1. All - Increased potential for sediment transport and deposition associated with new or augmented storage facilities.	Same as Alternative 2.

Table 3. Summary of Geology and Soils Impacts in the San Joaquin River Region (Page 1 of 3)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Soil salinity	Elevated soil salinity concentrations and mass in the southern and western portions of the valley threaten land productivity and downstream soils affected by applied and river channel water quality.	Conditions can be expected to worsen as additional salt load is imported to the valley and leached from soils by irrigation. More agricultural soils would be degraded or go out of production in more seriously affected areas.	Same as No Action impacts.	Some improvement and stabilization of conditions can be expected to the same degree that the salt loads contained in water exported to the San Joaquin Valley are reduced.	More improvement and stabilization of conditions can be expected to the same degree that the salt loads contained in water exported to the San Joaquin Valley is improved by diversion of good quality water through the Isolated Facility directly from the Sacramento River.
Soil selenium	Elevated soil selenium concentrations and mass in the southern and western portions of the valley threaten land productivity for agricultural crops and wetland plants (needed by waterfowl) and downstream soils affected by applied and river channel water quality.	Conditions can be expected to worsen as additional salt load is imported to the valley and selenium is leached from soils by irrigation and natural drainage from contaminated native soils on the west side. More agricultural and wetland soils would be degraded or go out of production in the more seriously affected areas.	Same as No Action impacts.	Some improvement and stabilization of conditions can be expected to the same degree that selenium loads contained in water exported to the San Joaquin Valley are reduced.	More improvement and stabilization of conditions can be expected to the same degree that selenium loads contained in water exported to the San Joaquin Valley is improved by diversion of good quality water through the Isolated Facility directly from the Sacramento River, thus avoiding the addition of ocean- and Delta-derived selenium loads (slight, but cumulative).
Subsidence caused by peat oxidation	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

Table 3. Summary of Geology and Soils Impacts in the San Joaquin River Region (Page 2 of 3)

Resource Category	Existing Conditions	No Action Alternative	Alternative 1	Alternative 2	Alternative 3
Subsidence caused by groundwater withdrawals	Subsidence caused by groundwater withdrawals has been a continuing problem in the San Joaquin Valley as exemplified by the results of the 1987 to 1992 drought.	Subsidence caused by groundwater withdrawals can be expected to continue and worsen as groundwater pumping continues and increases, to make up for surface and project water delivery shortages.	Minimal change compared to No Action Alternative. Promotion of conjunctive use practices that are part of the Water Use Efficiency Program would have the greatest potential to improve conditions.	Subsidence caused by groundwater withdrawals could be reduced as a result of development and delivery of additional water supplies to the valley. Promotion of conjunctive use practices that are part of the Water Use Efficiency Program also could improve conditions.	Subsidence caused by groundwater withdrawals could be reduced even more as a result of development and delivery of additional water supplies to the valley and significant improvements to water quality. Promotion of conjunctive use practices that are part of the Water Use Efficiency Program would have greater potential to improve conditions with better water quality.
Seismicity	Risk of activity	No change	No change	No change	No change
Mitigation strategies			Careful design of river channel and bank modifications, consistent with fluvial geomorphologic principles. Use of watershed and bank protection measures to reduce erosion. Minimize disruption of natural hydrologic regimes. Agricultural drainage and salt management programs, such as a drain to the ocean, could help mitigate high soil salinity and selenium concentration problems.		
NOTE: All = Applicable to all Configurations.					

Table 3. Summary of Geology and Soils Impacts in the San Joaquin River Region (Page 3 of 3)

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